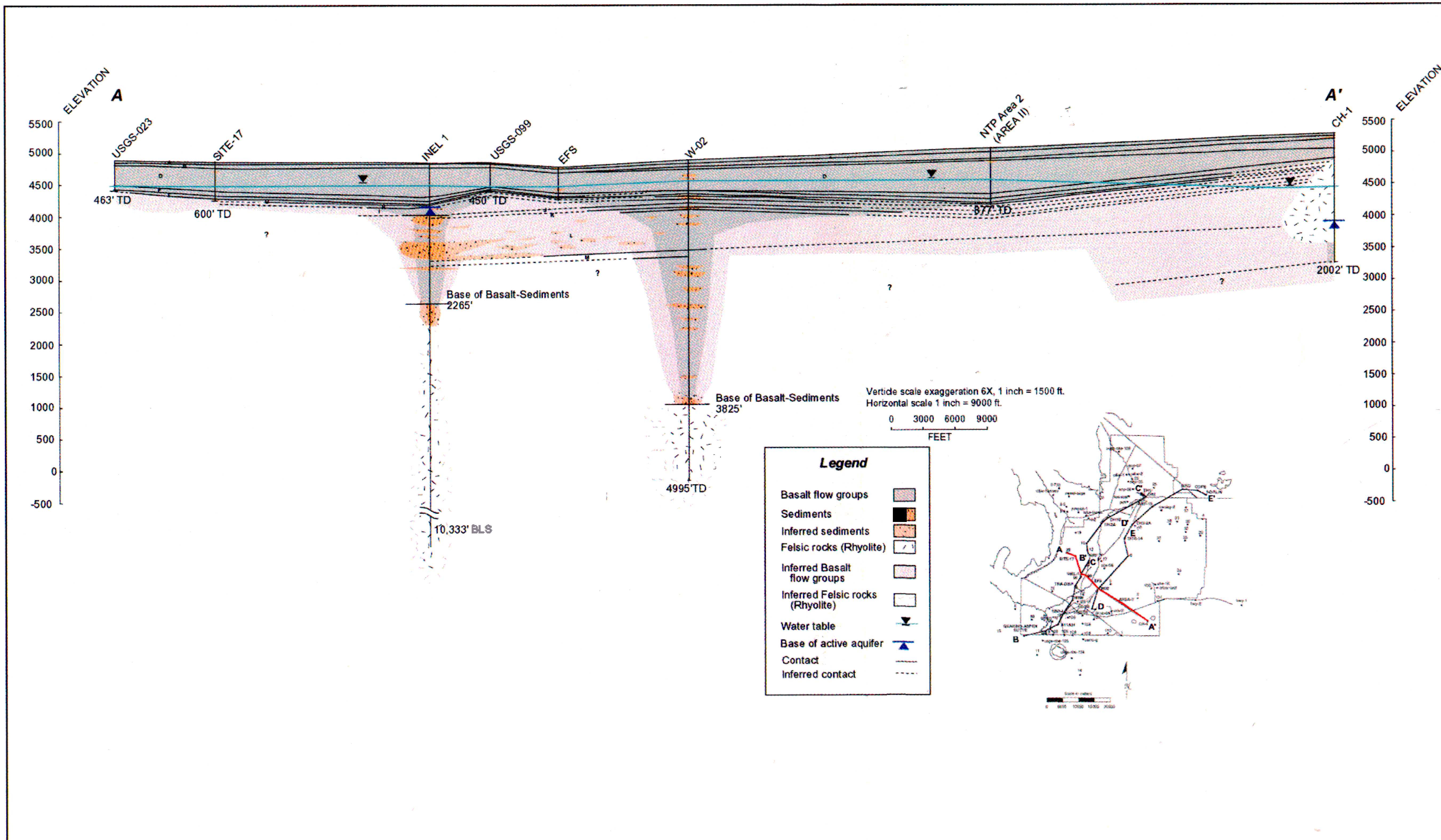
4.2.9 Sediment Interbed Distribution and Thickness

The distribution and lithology of sedimentary interbeds within the basalt section beneath the INEEL area exerts a strong influence on the flow of groundwater in both the vadose and saturated zones. It has been postulated that a thick sequence of fine-grained, relatively impermeable, lake sediments in the Mud Lake area impede groundwater flow and cause the steep gradient in the water table there (Lindholm et al. 1983, 1986; Garabedian 1989). In contrast, interbed distribution and lithology may enhance aquifer flow in the central part of the INEEL. The distributions of interbeds in a cross section that traverses the Big Lost River and extends from the eastern SRP margin to East Butte (see Figure 4-12) shows that there are numerous interbeds beneath the present course of the river, and that they become less numerous and thinner with distance from the river. There is likely to be a mixture of both coarse-grained (sands and sandy gravels representing channel and terrace deposits) and fine-grained (silts and silty clays laid down as overbank deposits) interbeds deposited by the Big Lost River as it was pushed back and forth by lava-flow emplacement during the past several million years. Eolian deposits of both loess and sand also are likely to be present. Based on drillhole information from throughout the INEEL, two interpretations of interbed distribution are shown in Figure 4-12, one assuming a very short horizontal continuity of interbeds (more of a river channel interpretation) and one assuming a long horizontal continuity of interbeds (perhaps representing broad flood-plain development such as the river exhibits today). In either case, however, there is a concentration of northward-elongated (perpendicular to the plane of the cross-section) alluvial interbeds in the central portion of the INEEL. The presence of these interbeds beneath most of the major facilities at the INEEL provides important controls on transport of water and contaminants in the vadose zone. This variation in the thickness and distribution of the sedimentary interbeds within the volcanic rocks on a site-wide basis is also presented in Cross-Sections A-A', B-B' and C-C', and D-D' and E-E', provided herein.

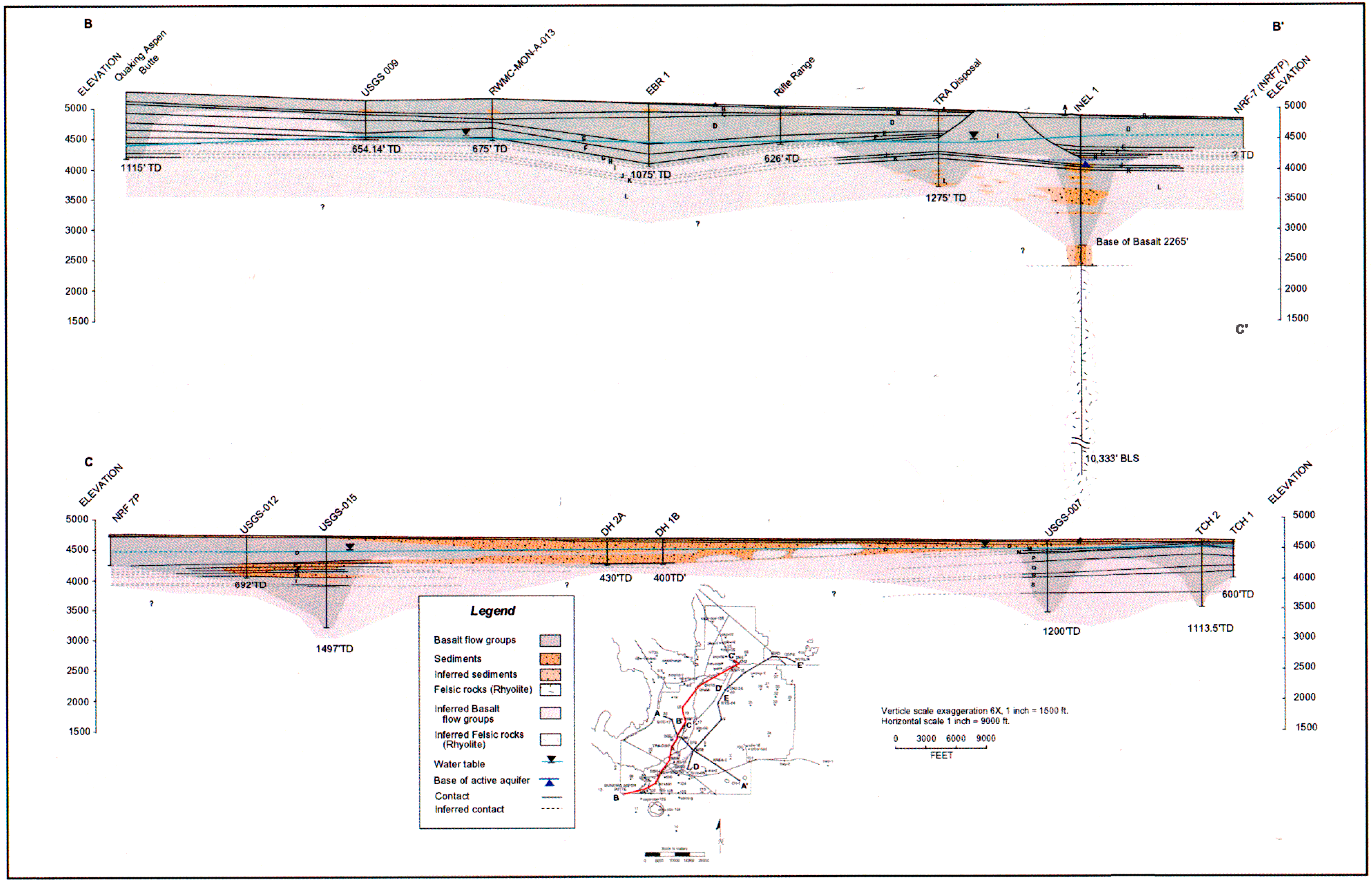
The thickness of sediment interbeds is extremely variable at both local (even within individual interbeds) and regional scales (see Figure 4-13). Thickness statistics were developed from the electronic database of well lithologies developed by Anderson (1996). Additional analysis shows that there is a tendency for interbed thickness to be greater in the northern than in the southern portions of the INEEL because of the presence of thick lake sediments there. There may be significant aliasing of the data because no attempt was made to account for different depths of wells. Some of the thickest beds occur only deep in the deepest boreholes, and because there are only a few deep boreholes, the data set is likely skewed toward thinner interbeds. In addition, Table 4-1 shows the thickness statistics for sediment interbeds from all INEEL wells.

Table 4-1. Thickness statistics for sediment interbeds from all INEEL wells.

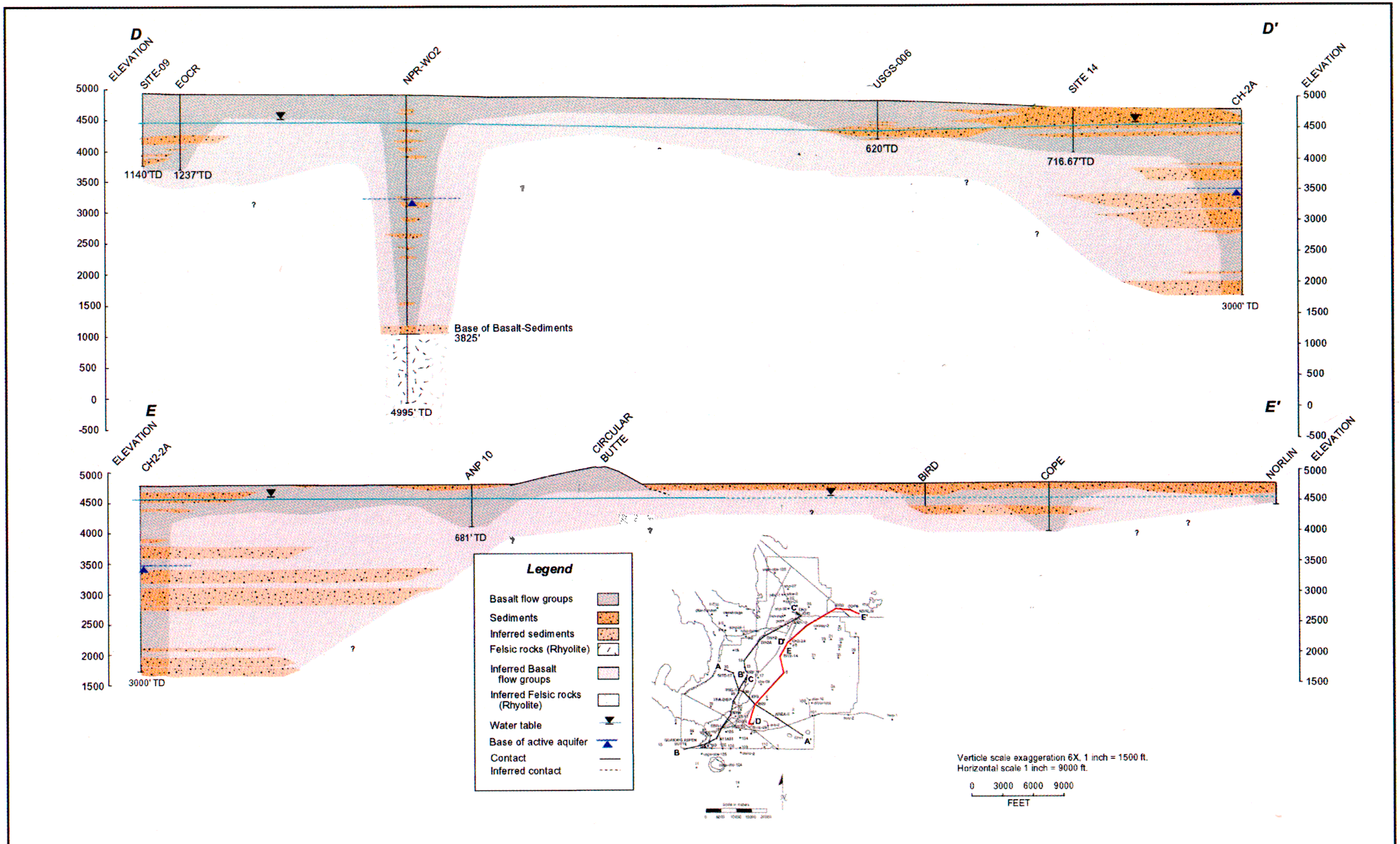
Minimum	1
Maximum	533
Median	9.0
Mean	10.9
Standard deviation	0.403277



Cross-Section AA'.



Cross-Section BB' and CC'.



Cross-Section DD' and EE'.

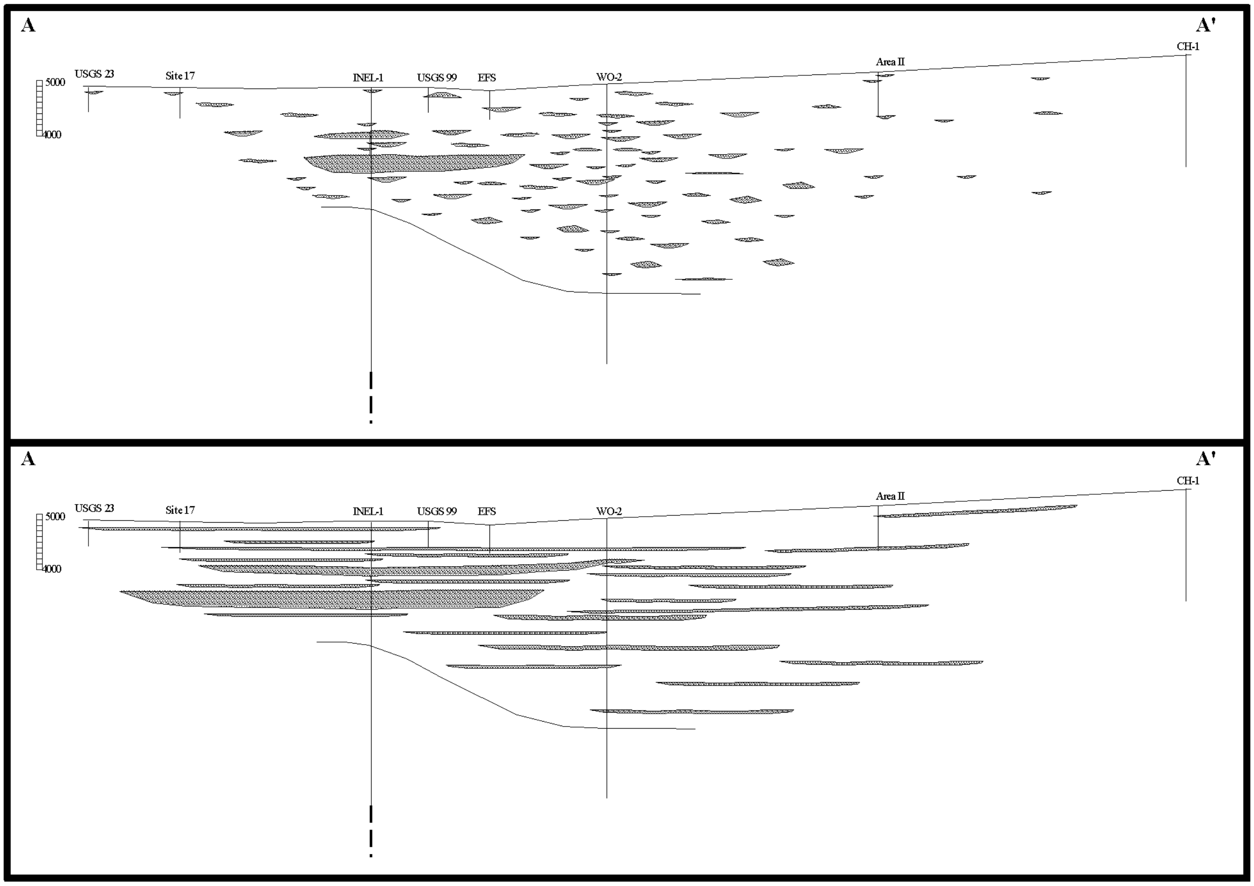


Figure 4-12. Sediment interbed distribution across the INEEL.

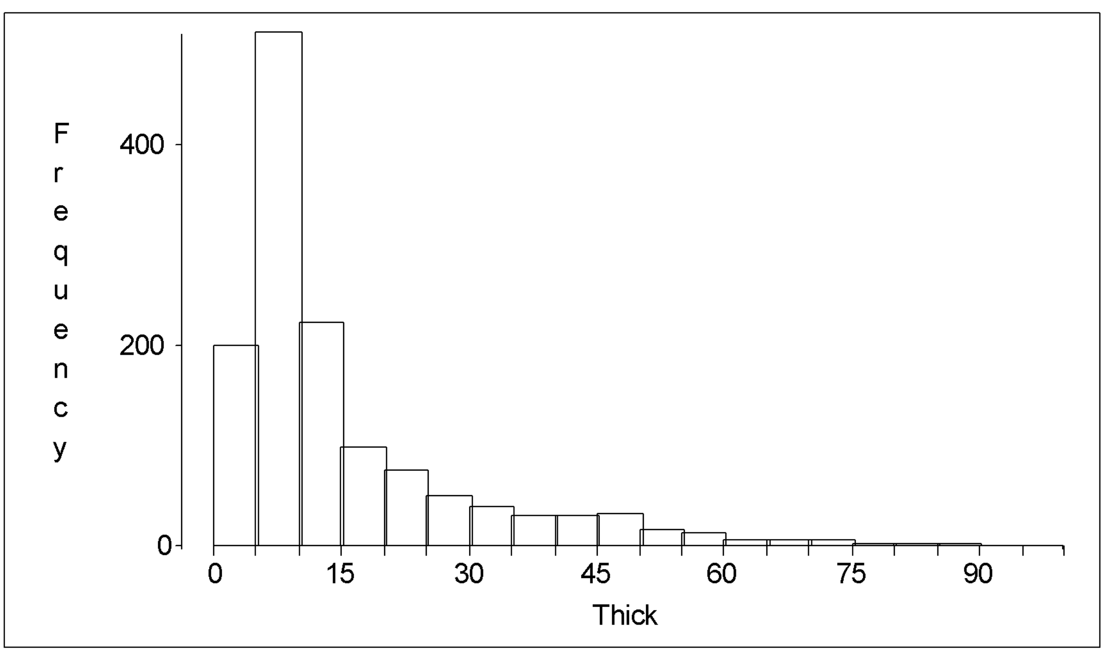


Figure 4-13. Histogram for sediment interbeds from all INEEL wells.

4.2.10 Characteristics of Basalt Lava Flows

4.2.10.1 Lava Flow Facies. During emplacement of eastern SRP basalt lava flows, molten rock is continuously supplied to the advancing flow front through lava tubes. The solidified crust on the top, bottom, and ends of the lava flows is kept inflated by the pressure of the molten material in the interior of the flow. As the flow front advances, the crust at the end of the flow is laid down and overridden by the new lava, and the upper crust is stretched, broken, and fissured by movements of magma beneath. This "bulldozer tread" type of emplacement mechanism produces distinctive facies within each lava flow. An idealized section showing distribution of vertical and horizontal facies variation in eastern SRP basalt lava flows is shown in Figure 4-14. From bottom to top, basalt lava flows typically are composed of a basal rubble zone, a lower vesicular zone, a massive columnar jointed zone, an upper vesicular and fissured zone, and a cap of platy-jointed crust.

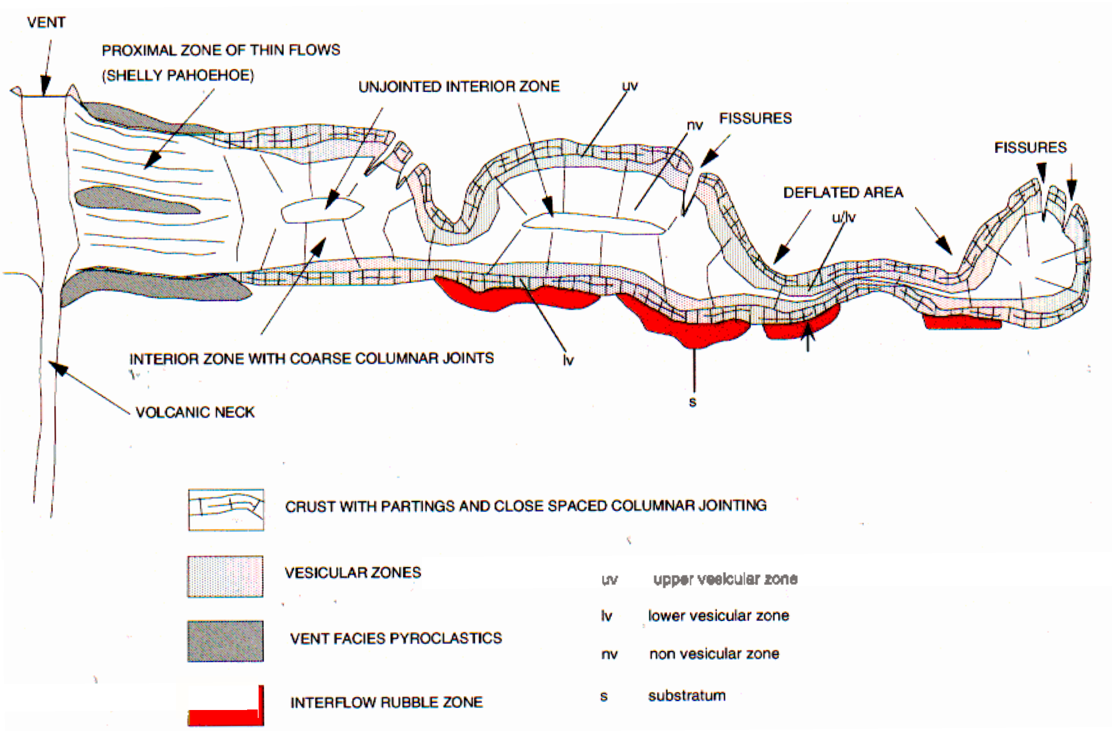


Figure 4-14. Longitudinal cross-section of a typical basalt lava flow on the eastern Snake River Plain.

The near vent facies of lava flows is typified by thin, vesicular, platy flows (shelly pahoehoe). Also pyroclastic ash and breccia layers are commonly interleaved within the thin flow layers. With distance from the vent, the shelly pahoehoe grades rapidly into the layered facies structure, described above, which typifies the medial and distal portions of the lava flow (see Figure 4-12). Deflation pits, in which solidified crust has subsided over areas where lava has drained away, are common throughout the flow but more numerous near the terminus.

4.2.10.2 Lava Flow Dimensions. There is a great range in length, area, and thickness of lava flows in the INEEL area (see Table 4-2). The length and area measurements are for lava flows exposed at the surface and are measured from geologic maps (Hackett, Smith, and Khericha 2000). The thickness measurements are mostly from drill hole information in the Radioactive Waste Management Complex area, augmented by measurements made of lava flow thickness in cliff faces in the Box Canyon area, to the west of the INEEL (Knutson et al. 1989, 1992).

Table 4-2. Statistics of lava flow dimensions.

	Length (km)	Area (km^2)	Thickness (m)
Minimum	0.1	0.5	1
Maximum	31	400	34
Range	30.9	399.5	33
Mean	12.4	96.5	?
Median	10	70	7
Standard deviation	7.9	94.2	?
Number of measurements	46	43	641

4.2.10.3 Seismic Hazards. Seismic hazards at the INEEL include both ground shaking and ground deformation. Ground shaking is a widespread phenomenon during earthquakes and usually affects large regions around the epicenter. Ground deformation is a more local phenomenon and usually occurs only on steep slopes (landslides caused by ground shaking) or in the immediate vicinity of the rupturing fault (fissures and scarps caused by fault displacement). Since most of the INEEL has flat land and very gentle slopes, landsliding is not a problem. Ground deformation could be a problem, however, in places near to fault rupture surfaces. This is important for only one small area near the northwest boundary of the INEEL.

Ground shaking is a seismic hazard at all places on the INEEL. The level of ground shaking depends on earthquake magnitude, distance from the source, and the attenuation characteristics of the material through which the seismic waves are transmitted. Potential sources of earthquakes include the major faults of the Basin and Range province just to the northwest of the INEEL (Figure 4-6), background seismicity of the eastern SRP, background seismicity of the Basin and Range province close to the INEEL, and seismicity associated with volcanism in volcanic rift zones. Because the major contributors to strong ground shaking hazard are the Lemhi and Lost River faults, the ground shaking intensity is greatest along the western boundary of the INEEL and gradually dissipates with distance to the southeast (Smith 1994; Woodward-Clyde Federal Services 1996).

The interlayering of basalts with high seismic velocity and soft sediments with low seismic velocity tends to attenuate or dampen seismic ground motion to levels lower than would be experienced if the interlayering were absent (Woodward-Clyde Federal Services 1996). Therefore, areas with great numbers of interbeds tend to have less ground motion than areas with few or no interbeds. Thick surficial sediments, however, tend to amplify ground motions.

4.2.10.4 Volcanic Hazards. Because the eastern SRP is a volcanic province with activity as recent as 2,000 years (Kuntz et al. 1992, Hackett and Smith 1992), volcanic hazards have been addressed in two studies (Volcanism Working Group 1990; Hackett, Smith, and Khericha 2000). The most significant volcanic hazard at the INEEL, inundation by basalt lava flows, has been shown to be less than 10^{-5} per year for any particular site, even within the most active volcanic rift zones on the INEEL and in the Axial Volcanic Zone (Volcanism Working Group 1990; Hackett , Smith, and Khericha 2000). Sites removed from volcanic rift zones and the Axial Volcanic Zone have even lower probabilities of inundation.

4.3 Hydrology

This section provides an overview of the hydrology at the INEEL.

4.3.1 Surface Water Hydrology

Surface water hydrology at the INEEL includes water from three primary streams that flow onto the INEEL in wet years and from local runoff caused by precipitation and snowmelt. Most of the INEEL is located in the Pioneer Basin into which the Big Lost River, the Little Lost River, and Birch Creek drain (see Figure 4-9). These streams receive water from mountain watersheds located to the north and northwest of the INEEL. The average annual discharge, upstream of the INEEL, for the Big Lost River (below the Mackay Dam), the Little Lost River, and Birch Creek is 8.9 m^3/sec (314 ft^3/sec), 2 m^3/sec (70 ft^3/sec), and 2.2 m^3/sec (78 ft^3/sec), respectively (DOE 1991). Stream flows often are depleted before reaching the INEEL by irrigation diversions and infiltration losses along stream channels. Most of the flow of the Little Lost River and Birch Creek is diverted for irrigation before it reaches the INEEL. The Pioneer Basin has no outlet; therefore, water flowing onto the INEEL either evaporates or infiltrates into the ground (Barraclough, Lewis and Jensen, 1981 and Irving 1993).

The Big Lost River is the major surface water feature on the INEEL. Recharge to the SRP aquifer from flow during wet years is significant. Its waters are impounded and regulated by Mackay Dam, which is located approximately 6 km (4 mi) north of Mackay, Idaho and approximately 40 miles to the northwest of the INEEL. Upon leaving the dam, waters of the Big Lost River flow southeastwardly past Arco and onto the eastern SRP. During dry periods, flow does not reach the INEEL. Flow in the Big Lost River that actually reaches the INEEL is either diverted at the INEEL diversion dam for flood-control and spread to areas southwest of the RWMC, or continues northward across the INEEL in a shallow channel to its terminus at the Lost River sinks. The INEEL flood-control diversion system was constructed in 1958 to reduce the threat of floods from the Big Lost River on that part of the site. The diversion dam can divert flow out of the main channel to spreading centers A, B, C, and D. During the winter months, nearly all flow is diverted to avoid accumulation of ice in the main channel and preclude the possibility of flooding the INEEL facilities. Flow in the sinks is lost to evaporation and infiltration (Barraclough, Lewis and Jensen, 1981 and Irving 1993).

The Little Lost River drains from the slopes of the Lemhi and Lost River ranges. Springs below Gilmore Summit in the Beaverhead Mountains and drainage from the surrounding basin flow in a southeasterly direction between the Lemhi and Bitterroot ranges to the southeast are the source for Birch Creek. Most of the flow of the Little Lost River and Birch Creek is diverted for irrigation before it reaches the INEEL. During the winter months, when water is not used for irrigation, water is returned to channels on the INEEL at the north end of the Site in which the water infiltrates into channel gravels, recharging the aquifer (Barraclough, Lewis and Jensen, 1981 and Irving 1993).

4.3.2 Groundwater Hydrology

The SRP aquifer consists of a series of saturated basalt flows and interlayered pyroclastic and sedimentary materials that underlie the SRP. The SRP aquifer, approximately 322 km (200 mi) long and 65 to 95 km (40 to 60 mi) wide, covers an area of approximately 25,000 km^2 (9,600 mi^2). It extends from Hagerman, Idaho, on the west to near Ashton, Idaho, northeast of the INEEL.

The permeability of the aquifer is controlled by the distribution of highly fractured basalt flow tops and interflow zones with some additional permeability contributed by vesicles and intergranular pore spaces. The variety and degree of interconnected water-bearing zones complicate the direction of groundwater movement locally throughout the aquifer (Barraclough et al. 1981). Although a single lava flow may not be a good aquifer, a series of flows may include several excellent water-bearing zones. If the sequence of lava flows beneath the SRP is considered to constitute a single aquifer, it is one of the world's most productive (Mundorff et al. 1964).

The influence of geologic structures such as the "Circular Butte-Kettle Butte Rift zone", "Lava Ridge-Hell Half Acre Rift Zone", and the "Arco Rift Zone" that penetrate the INEEL site normal to the trend of the regional groundwater flow is uncertain due to limited data. Similarly, the effects of volcanic dikes, necks, and fissures on groundwater flow are not well understood. Additional information is needed to fully evaluate the effects of large scale geologic structures on the groundwater flow regimes.

A 1974 report on the geochemistry of water at the INEEL (Robertson, Schoen, and Barraclough 1974) estimated that as much as 2.5×10^{12} m^3 (2 billion acre-ft) of water may be stored in the aquifer, approximately 6.2×10^{11} m^3 (500 million acre-ft) of which are recoverable. Later estimates suggest that the aquifer contains approximately 4.9×10^{11} m^3 (400 million acre-ft) of water in storage. The aquifer discharges approximately 8.8×10^{9} m^3 (7.1 million acre-ft) of water annually to springs and rivers. Pumpage from the aquifer for irrigation totals approximately 2.0×10^{9} m^3 (1.6 million acre-ft) annually (Hackett et al. 1986).

Recharge to the SRP aquifer from within INEEL boundaries is primarily in the form of infiltration from the rivers and streams draining the areas to the north, northwest, and northeast of the SRP. In most years, spring snowmelt produces surface runoff that accumulates in depressions in the basalt or in playa lakes. On the INEEL, water not lost to evapotranspiration recharges the aquifer because the INEEL is in a closed topographic depression. Significant recharge from high runoff in the Big Lost River causes a regional rise in the water table over much of the INEEL. Water levels in some wells have been documented to rise as much as 1.8 m (6 ft) following very high flows in the Big Lost River (Pittman, Jensen, and Fischer 1988). Figure 4-15, prepared by Dan Ackerman of the U.S. Geological Survey (USGS) for an October 24, 2000 presentation, presents an estimation of the water budget for the eastern SRP aquifer.

Water table contours for the SRP aquifer below the INEEL are depicted in Figure 4-16. The regional flow is to the south-southwest, though locally the direction of groundwater flow is affected by recharge from rivers, surface water spreading areas, pumpage, and heterogeneity in the aquifer. Across the southern INEEL, the average gradient of the water table is approximately 0.95 m/km (5 ft/mi) (Lewis and Goldstein 1982). Depth to water varies from approximately 60 m (200 ft) in the northeast corner of the INEEL to 305 m (1,000 ft) in the southeast corner.

The USGS estimated (Mann 1986) the thickness of the active portion of the SRP aquifer at the INEEL to be between 75 and 250 m (250 and 820 ft). Drilling information from the deep geothermal test well (INEL-1) located 4 km (2.5 mi) north of the TRA suggests an active flow system thickness of between 134 and 250 m (440 and 820 ft) (Mann 1986) while temperature logs from the same well indicate that the flow system is approximately 100 m thick.

Studies of drill cores from several of the deep exploration drill holes on the INEEL (most notably CH2-2A and WO-2) show that secondary mineralization and alteration significantly reduce the porosity and permeability of basalt at depths of 370 to 550 m (1,200 to 1,800 ft). Geophysical logs also show that water movement and water content drop off rapidly at this depth interval. Together, logs and cores suggest that the bottom of the active portion of the aquifer lies in the 370 to 550-m (1,200 to 1,800-ft) depth range.

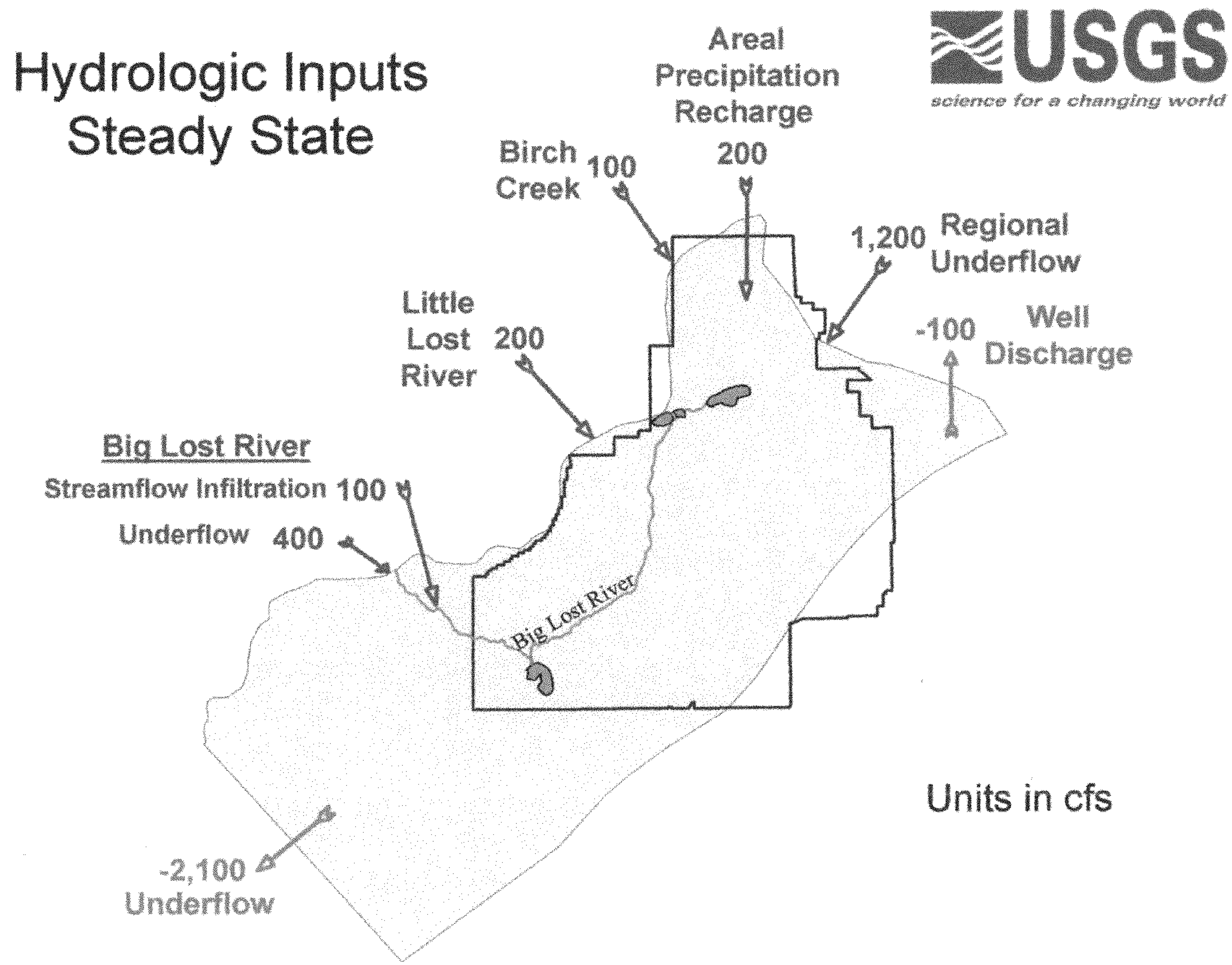


Figure 4-15. Water budget for the area of the INEEL (used by permission of the USGS).

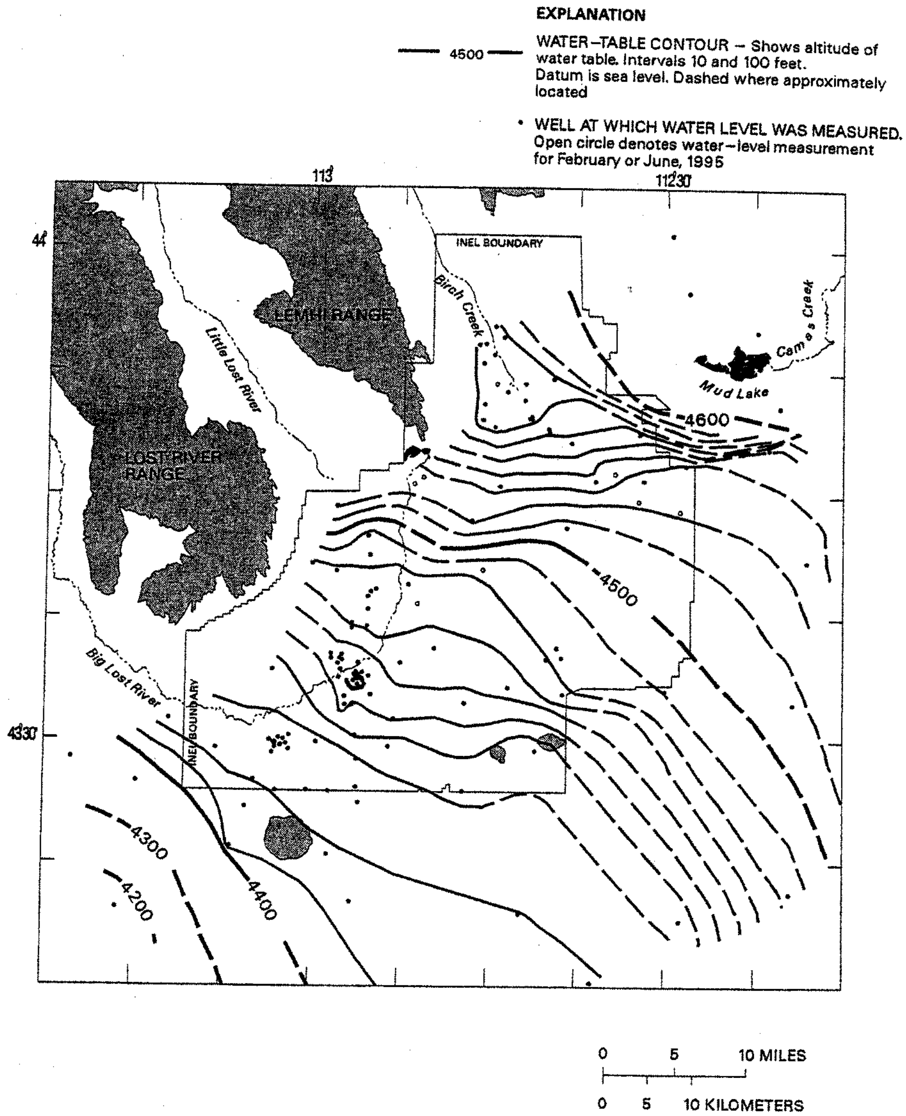


Figure 4-16. Altitude of the water table for the Snake River Plain aquifer in the vicinity of the INEEL, March through May 1995 (USGS 1995).

4.3.3 Vadose Zone Hydrology

The vadose zone is the region of the subsurface that extends from land surface to the water table. It is a particularly important component of the INEEL hydrologic system. The thick vadose zone limits impacts to groundwater by acting as a buffer or filter thus slowing or preventing many contaminants from reaching the SRP aquifer. Water is the primary mechanism for most chemical transport in the vadose zone, although vapor transport can be significant for volatile constituents. Water movement is generally moving under unsaturated steady-state conditions, although episodic fluxes occur during the spring snowmelt or if the site is near the Big Lost River or an infiltration pond. These pulses of water may drive water and contaminants meters in a matter of days or weeks. Information on sources of water, geology, and topography can be used to determine areas that have a higher probability of recharge and subsequent movement of contaminants.

Collection of water at the surface is the primary factor controlling recharge to the subsurface. Concentrating water in streams, infiltration ponds, or surface ponding can allow standing water to infiltrate into openings in the sediment or basalt. This moisture can move rapidly below the depth of evapotranspiration where it will then continue to move under the force of gravity. Small precipitation events or diffuse sources of water will generally move at a slower rate through the sediments and may be removed by evapotranspiration. Course texture and disturbance of the surficial sediments can allow moisture to infiltrate more rapidly into the subsurface increasing the recharge rate if there are significant sources of water.

The movement of water through thick sequences of basalt flows and sedimentary interbeds can be relatively rapid during periods of saturation. Morris et al. (1963) observed the rise of the water table at a depth of about 142 m (465 ft) in Well 5 about 15 to 20 days after the beginning of runoff from the rapid Spring thaw in 1962. The water table rose from 142 m (466 ft) to about 141 m (463 ft) below land surface. Barraclough et al. (1967) reported that the water level in Well 78 [62 m (203 ft) deep and 72 m (235 ft) from the Big Lost River] started to rise within 4 days after the water first flowed in the Big Lost River channel. Pittman et al. (1988) reported that water levels in some wells at the INEEL rose as much as 1.8 m (6 ft) or more in a few months following high flows in the Big Lost River. In a large field experiment, water infiltrating from a 6.6-acre circular pond advanced vertically through the basalt vadose zone at a rate of about 5 m/day (16.4 ft/day) (Wood and Norrell 1996). Water flow was confined within a vertical cylinder, the top of which was defined by the infiltration basin. A sedimentary interbed at the 54.5-m (180-ft) depth served as an impediment to the vertical water flow and directed the water laterally. These effects are in response to ponding of water at the surface and large volumes of water. Sisson and Hubbell (1999) monitored the movement of the wetting front through basalt from infiltration of snowmelt with minor ponding (<2 cm) at land surface; this front moved from land surface to a depth of 50 ft (15 m) in about 3 days.

4.3.4 Perched Water

Perched water bodies may form when a sufficient quantity of water moves downward through a higher conductivity zone and encounters a lower conductivity zone. Perched water zones have been identified at TRA, ICPP, TAN, RWMC, and areas adjacent to the Big Lost River (Figure 1-2). Sources of water that can form or may have formed perched water within the vadose zone include past wastewater disposal to injection wells, percolation ponds, ditches, leaks in facility piping systems, surface ponding of water from snowmelt, and groundcover irrigation.

The presence of perched water can increase flux rates, form preferential flow paths and allow for more dissolution of contaminants. Unsaturated hydraulic conductivity of porous materials is a function of moisture content; increasing moisture content corresponds with higher hydraulic conductivity. The relationship is nonlinear and thus small increases in water content can correspond to orders of magnitude increases in flux rates. As saturated conditions form, water can enter larger pores and fissures that were barriers to flow under unsaturated conditions. Typically, the large cooling fractures in the basalt will not transmit water until full saturation is attained. Once saturation is attained, water can enter the large opening and move large distances vertically or horizontally. This preferential flow may allow water to move in unpredictable directions laterally with water moving in nearly any direction. Perched water adjacent to the contaminants may allow dissolution of additional solute that then can be transported as the moisture moves into the underlying geologic media.

The geohydrologic characteristics of the unsaturated zone underlying these sites differ with respect to basalt and sediment lithology, stratigraphic unit thickness, sources of water and physical orientation. The degree of saturation varies both horizontally and vertically. Though these differences exist, the features that control the formation of perched groundwater zones may be common to the sites. Despite numerous wells being drilled at various sites it is frequently difficult to detect, monitor, and determine the perching mechanisms using conventional drilling and monitoring techniques. Tools and techniques to detect and monitor these perched water zones are only now becoming available.

At least four generalized lithologic features may contribute to perched groundwater formation. The sharply contrasting lithologic features of basalt flows and sedimentary interbeds provide mechanisms for the development of perched groundwater bodies in the unsaturated zones. First, the dense, unfractured interior of basalt flows may inhibit unsaturated groundwater movement and contribute to the formation of perched water zones within the overlying fractured basalt. Second, the vertical hydraulic conductivity of a sedimentary interbed may be lower than that of an overlying (fractured) basalt flow. Third, permeability alterations that occur in the baked zones between basalt flows may result in different hydraulic characteristics of the underlying flow, which would reduce vertical hydraulic conductivity. Fourth, sedimentary and chemical in-filling of the highly fractured upper contact surface of a basalt flow can reduce vertical hydraulic conductivity. The rate and volume of water being transported through the unsaturated zone, as well as the hydrogeologic characteristics of the media, determine if perched water is formed.

At TRA, a vertical sequence of discontinuous perched water zones formed in unsaturated basalt flow groups and sedimentary interbeds have been observed. Thick sections of basalt and sedimentary interbeds are saturated near the TRA ponds. The perched water is over 20 m (60 ft) thick in places and extends laterally over 1000 m in a southeast direction, counter to the prevalent groundwater flow direction. Geologic structures may influence the extent of these perched water zones and the vertical flow of water between zones. Anderson (1991) described a subsurface structural dome northeast of TRA. Domal deformation of basalt and sedimentary interbeds may limit the formation of perched groundwater zones to the northeast of the TRA ponds (Cecil et al. 1991).

The discharge of wastewater from two infiltration ponds at INTEC caused perched groundwater zones to form in the vicinity of the ponds. At least four perched groundwater zones have been identified beneath the infiltration ponds. These include a zone of saturation in the surficial alluvium and three separate zones in the underlying basalt and sedimentary interbeds. By 1986, perched groundwater zones had formed at USGS Well 51 at the depth intervals from 9 to 31 m (30 to 104 ft), 40 to 54 m (134 to 178 ft), and 80 to 98 m (266 to 322 ft). A thin perched groundwater zone formed at the surface alluvium-basalt interface because the alluvium is relatively more permeable than the underlying basalt (Cecil et al. 1991).

Perched water at TAN occurs below the TSF waste pond. The lateral extent of the perched water zone is defined by wells in the area. Only two wells in the area penetrate the perched water zone. The data from these wells suggest that the extent of the perched water is limited to beneath the wastewater pond. The perched water zone in this area lies at a depth of approximately 13.6 to 15.2 m (45 to 50 ft) at the first soil and basalt interface.

From 1976 to 1977, wet zones were identified in vadose zone wells at the RWMC (Barraclough, 1976, Hubbell; 1990; Cecil et al. 1991). Perched groundwater was identified intermittently in two zones above sedimentary interbeds at about 80-90 ft and 222 to 246 ft below land surface (Hubbell, 1990). Drilling and monitoring data suggested that the perched water was discontinuous at this site. Water level data from USGS 92, in the center of the SDA, suggested that water recharged to the spreading areas about 1300 m (4400 ft) might be impacting this well (Hubbell, 1990). Recently, the USGS placed tracers in the Spreading Area west of the RWMC (Brennon Orr, personal communication). Tracer was detected in USGS Well 92 in the center of the RWMC above the 73 m (240 ft) interbed about 90 days following tracer introduction. This suggests a water movement of over 1,300 m (4,300 ft) laterally and 70m (230 ft) vertically over three months. Wells at the Large Scale Infiltration Test site, 1.6 km (1 mi) east of the spreading areas also had tracer in them following the tracer introduction. This suggests that the formation of perched water may be widespread near the spreading areas.

4.3.5 Vadose Zone Hydrologic Conceptual Model

This section presents the current level of understanding of water movement in the subsurface at the INEEL (Wood 2000). It provides a discussion of the various mechanisms that are thought to control water movement in the various portions of the subsurface. The level of confidence varies between the sediment portions of the subsurface where the flow mechanisms are reasonably well understood and the fractured basalt portions where the mechanisms are less well known. The section is organized in terms of the general movement of water in the subsurface, following the path of water from land surface to the Snake River Plain aquifer. Figure 4-17 graphically shows the vadose zone at the INEEL, the sources of water and the movement of water in different parts of the vadose zone. This conceptual model is derived from both field observations from a variety of investigations conducted at the INEEL since the 1960s and from hypotheses (Wood 2000).

In general, the movement of water in the INEEL subsurface is extremely complex to describe. This is due to spatial variability of hydraulic properties, temporal changes in the hydrologic regime caused by seasonal changes, limited access locations with vertical wells in areas where horizontal permeability is a dominant control, heterogeneous waste disposal, lack of integrated sampling opportunities in the vadose zone like pumping tests in the aquifer, and limited duration of monitoring activities. With these limitations in mind, the remainder of this section describes a vision of water movement in the subsurface.

4.3.5.1 Sources of Water for Vadose Zone Infiltration at the Surface. Several sources of water contribute to water movement in the vadose zone (Wood 2000). Direct precipitation contributes some water to the subsurface. The annual precipitation at the INEEL is approximately 22 to 23 cm/year. A variable portion of this annual precipitation is received as snow, which accumulates until a melting event occurs. Runoff of precipitation can occur during substantial rain events or from snowmelt events. Flooding from runoff in local basins on the INEEL can supply substantial amounts of water when those events occur.

In addition to precipitation, another source of water is surface water that flows onto the INEEL from several drainages to the northwest. These drainages are the Big Lost River, the Little Lost River, and Birch Creek (Figure 4-2). Depending on the snow pack and precipitation that occur in a particular year, these water sources may flow all year, or they may be completely used up for irrigation prior to reaching the INEEL. The amount of water reaching the vadose zone from these surface water sources depends on the proximity to the surface sources (Wood 2000).

A third source of water that contributes to water movement in the vadose zone is human activities at the INEEL facilities. These sources include sewage treatment ponds, infiltration galleries, and disposal of process water at some facilities. Where these sources exist, they usually supply a far greater amount of water to the subsurface than precipitation (Wood 2000).

4.3.5.2 Infiltration into Surficial Sediments. Infiltration of water from the surface into the subsurface is known to be spatially and temporally variable. At the INEEL, infiltration primarily occurs in early spring, when the accumulated snow pack melts and there is essentially no evapotranspiration.

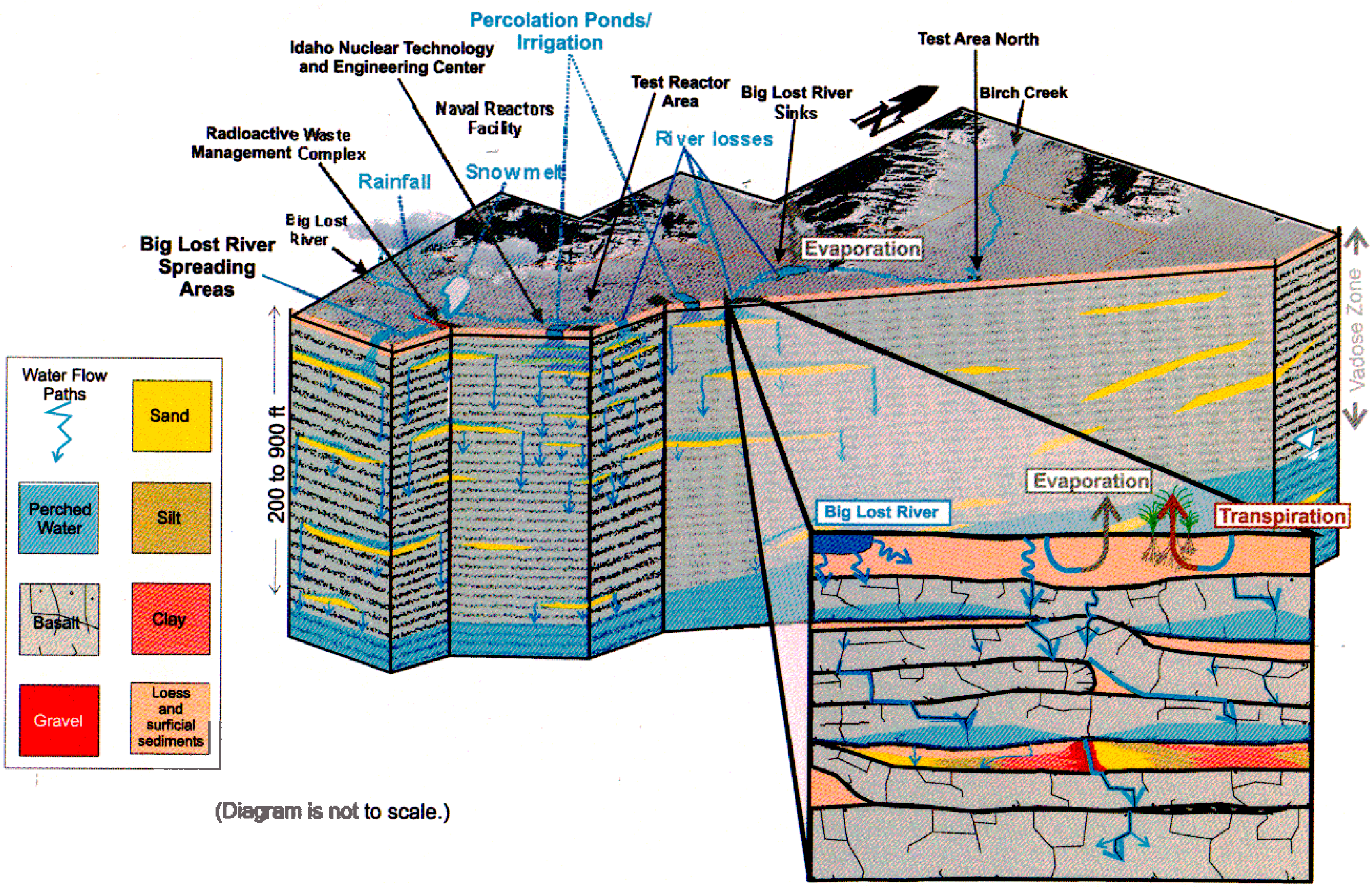


Figure 4-17. Geohydrologic conceptual model of the vadose zone at the INEEL.

The primary controls on where, when, and how much water infiltrates at any one place are the following (Wood 2000):

- The degree of soil freezing (results from cold weather conditions and a lack of snow pack)
- Disturbances of natural layering in soils that disrupt low-permeability layers, or disrupts high-permeability layers that act as capillary barriers
- Depressions in surface topography that collect meltwater
- The magnitude of potential evapotranspiration that is occurring and the depth to which evapotranspiration affects water movement
- Spatial variability in hydraulic properties
- Presence of preferential pathways that allow rapid infiltration.

The controls on infiltration listed above are primarily for infiltration that is occurring as a result of widespread precipitation or snowmelt. In addition to this infiltration mechanism, infiltration occurs from the surface sources and human sources under saturated conditions. The controls on this type of infiltration include the following:

- Hydrologic properties of the sediments under the river, spreading areas, or infiltration ponds
- Height of water or head
- Duration of water being present.

Once the water infiltrates into the surficial sediments past a depth where it can be affected by evapotranspiration, it primarily continues to move downward under the influence of gravity, though capillarity can exert an influence that can move water laterally from wetter to drier locations (Wood 2000).

4.3.5.3 Water Movement from Surficial Sediments into Basalt. As water moves downward through the surficial sediments, it eventually encounters an underlying fractured basalt flow (Wood 2000). Multiple mechanisms are possible by which water can continue moving downward into this lithologic unit. These are illustrated graphically in Figure 4-18. All these mechanisms likely occur to varying degrees. The difficulty is in assessing their relative contribution to net water movement under a range of hydrological conditions from dry to wet.

The first mechanism illustrated in the figure is movement from the pore space of the sediments into the pore space of the matrix. This process likely takes place predominantly in locations where there is not sufficient water to elevate moisture conditions at the interface.

The second mechanism is closely related to the first and consists of water movement from the pore space in the sediments into a very small aperture fracture that exerts a capillary imbibition force on the sediment pore water. This process, similar to the first, also likely takes place in predominantly drier locations.

The third mechanism describing water movement at this interface consists of lateral movement of water along the interface (Wood 2000). This movement would occur when the moisture flux moving vertically through the surficial sediments is greater than the hydraulic conductivity of the underlying basalt matrix, and when there are no open fractures in the basalt. This lateral movement could occur with or without the presence of perched water. If perched water conditions form, the magnitude of the lateral flux could be greater. This horizontal movement of perched water is believed to have been observed in neutron access tube moisture monitoring in the CFA landfills (Keck et al. 1995). Because the vertical permeability of the basalt matrix is generally less than the overlying sediments, it is likely that some horizontal movement occurs frequently.

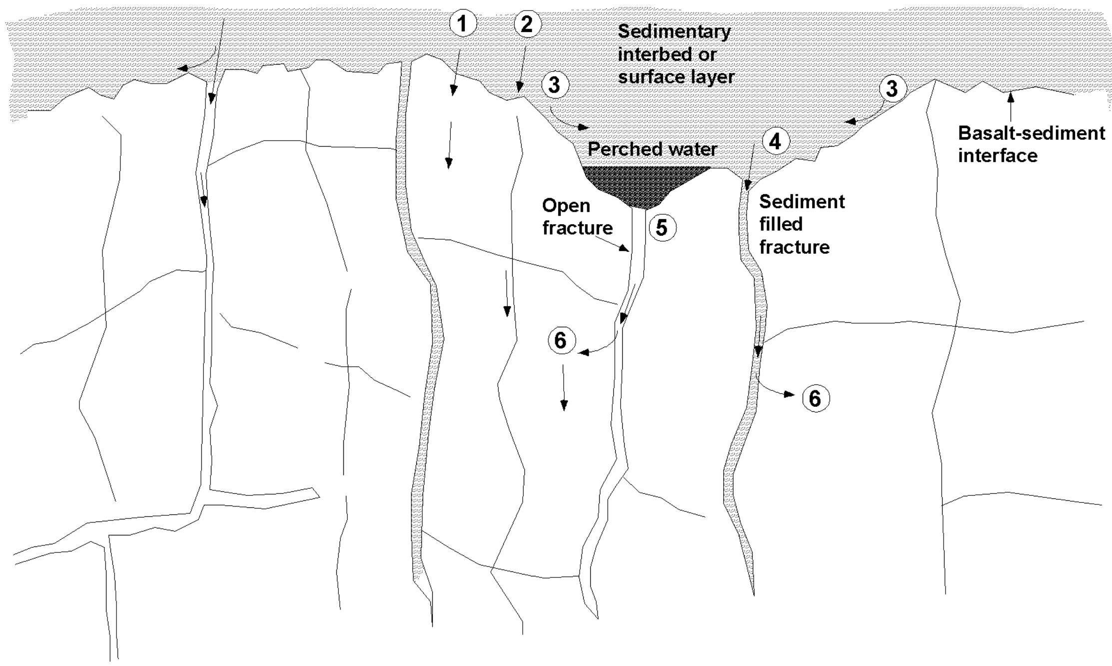


Figure 4-18. Possible mechanisms by which water can move across a sediment/basalt interface.

A fourth possible mechanism of water movement across this interface is when water moving laterally or vertically encounters a sediment-filled fracture into the underlying basalt. The sediment in the fracture is derived from the sediment overlying the fracture and will have a similar hydraulic conductivity allowing water to move vertically downward through it (Wood 2000).

The fifth, and potentially dominant, mechanism by which water crosses the sediment-basalt interface occurs when perched water accumulates at the interface and encounters an open fracture. Depending on its aperture, the fracture will likely not allow water to enter until perched conditions occur. Once perched conditions occur, an air-entry potential is reached and a pulse of water will enter the fracture. Depending on the conditions, this pulse may have a greater magnitude of water than all the previous mechanisms combined.

This presentation of water movement from the surficial sediments into the basalt conveniently ignores some complications, such as the presence of a low-permeability clay layer at some locations, such as is often found at the base of the surficial sediments inside the Subsurface Disposal Area. In these cases, the dominant mechanisms may be different, or they may be the same but even more dominant because water may perch and move laterally even farther until it encounters a fracture or preferential pathway into the fractured basalt (Wood 2000).

4.4 Idaho National Engineering and Environmental Laboratory Soils

A soil map of the INEEL (Figure 4-19) depicts the distribution of the various landscapes. The alluvial deposits follow the courses of the modern Big Lost River and Birch Creek. The playa soils are located in the north-central part of the INEEL Site. The colluvial sediments are located along the western edge of the Site. Silt- and sand-covered lava plains occupy the rest of the INEEL landscape.

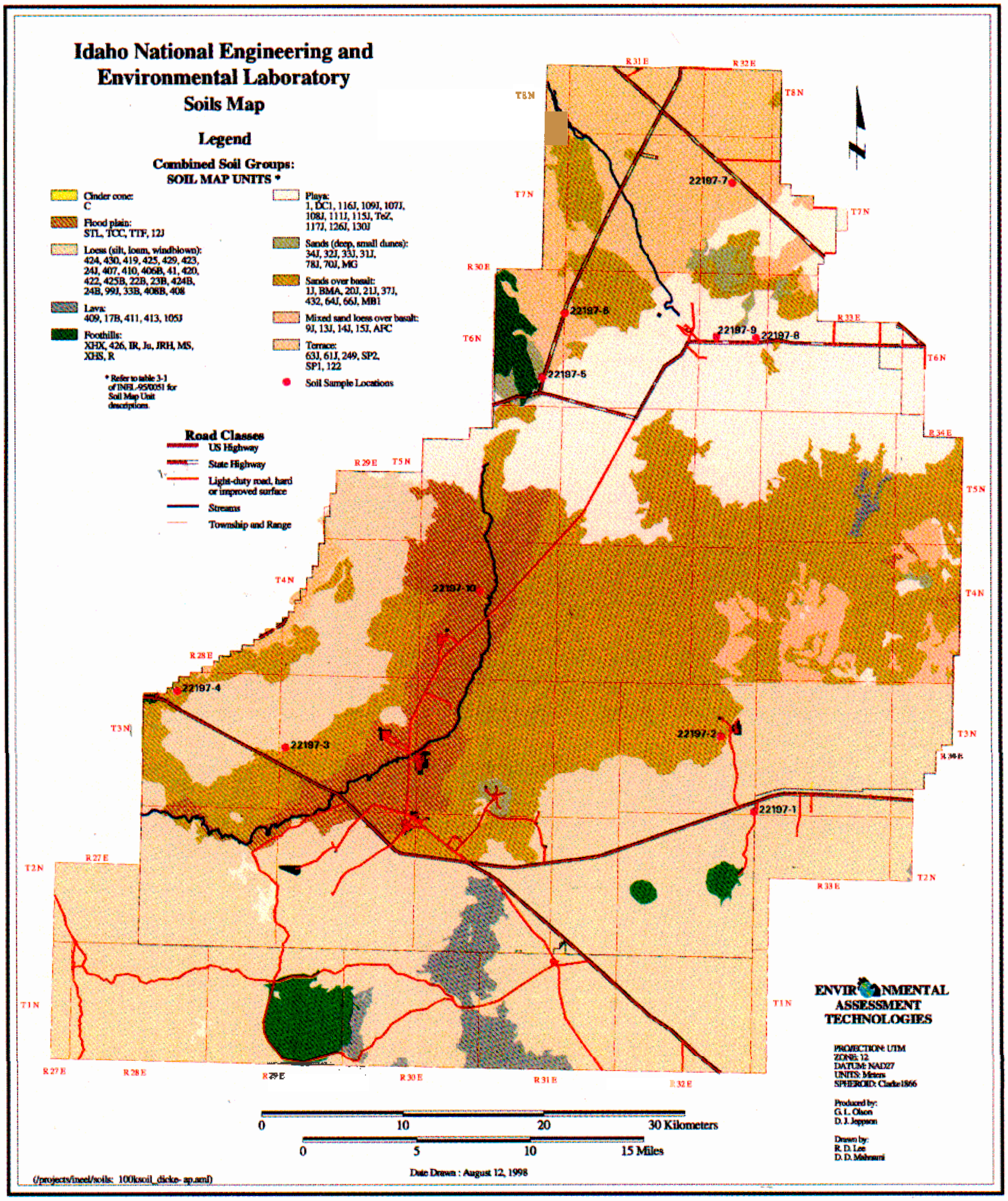


Figure 4-19. INEEL soil map.

4.4.1 Wind-Blown Sediments Over Lava Flows

Wind-blown sediments over lava flows are a common soilscape at the INEEL. The soils formed in these sediments range in texture from the fine-grained wind-blown glacial flour (loess) left behind by retreating glaciers during the Pleistocene epoch to eolian sand believed to have originated from the Big Lost and Snake rivers and from the shorelines of the ancient Lake Terreton. Dating of the loess with thermoluminescence and radiocarbon methods indicates that at least two distinct episodes of loess accumulation were represented on the INEEL. The youngest loess was deposited between 10,000 and 40,000 years ago, and the older loess was deposited about 60,000 to 80,000 years ago. Soils developed in the two deposits are markedly distinct. Subsoil in the younger soil contains high amounts of carbonates that have accumulated over the years of low rainfall and high evaporation. In contrast, the older soil (paleosol) was developed when effective precipitation was higher. Consequently, salts have been leached out of the subsoil, and fine particles (clays) have been deposited from the surface to the subsoil. Subsoil horizons of the older soil have relatively high amounts of clay rather than carbonates.

4.4.2 Alluvial Deposits

Deposits transported by rivers can be found in the flat expanses of the Big Lost River, Little Lost River, and Birch Creek alluvial plains. River action has truncated the former undulating lava landscape, leaving behind a layer of rounded river rock beneath a blanket of silty and sandy sediments.

The Big Lost River drains about 3,626 km^2 (1,400 mi^2). It enters the INEEL Site on the southwest end, flows east, then flows northward, and terminates in the Big Lost River sinks. Three recognized terraces of the Big Lost River are located on the INEEL. Around the Test Reactor Area (TRA), older deposits are capped with desert pavement and present accumulated salts in the subsurface at a depth of about 25.4 to 30.5 cm (10 to 12 in.). Typically, the soils are sands with gravel to loams with gravel or loamy sands, with low water-holding capacity and high permeability. Younger deposits generally do not exhibit a well-developed carbonate-enriched subsurface horizon, and most are not capped with desert pavement.

Birch Creek originates from springs below Gilmore Summit in the Beaverhead Mountains and terminates on the INEEL in an area called the Birch Creek playa. The Birch Creek alluvial deposits on the INEEL are generally loams with gravel. The playa deposit, in contrast, is described in the U.S. Department of Agriculture (USDA) soil classification as a deep, calcareous, alkaline, silty clay loam, or silty clay.

Alluvial plains are among the most valued landscapes because they provide flat terrain, subsurface gravels that are relatively easy to excavate, increased moisture and associated higher soil productivity, and desirable animal habitat. Most of the facilities at the INEEL have been located within alluvial plains. Gravel pits on the north end of the INEEL Site are located within the cobbles and gravels deposited by Birch Creek.

Near the Central Facilities Area (CFA), several gravel pits are located within the deposits of the Big Lost River. Some of the pits are located at a considerable distance from the modern channel and mark the extent of the river during the glacial Pleistocene epoch.

4.4.3 Lacustrine Deposits, Playas, and Sand Dunes

Another major landscape feature at the INEEL is the playa or desert lake basin. The modern-day playas at the INEEL are the Birch Creek playa and the Big Lost River sinks. These basins, located at the terminuses of the Big Lost River and Birch Creek, contain a thick layer of fine-grained sediments. The ancestral Lake Terreton occupied much of the northern part of the INEEL and is now overlain in many areas by sand dunes or elongated sand "trains." The ancestral lake was once a shallow (8 m [26 ft]) lake that covered about 150 km^2 (58 mi^2) and filled its basin as recently as 700 years ago. The lake was probably originally fed by both the Big Lost River and Birch Creek, and the high stage of the lake is estimated to be at an altitude of about 1,463 m (4,800 ft) above mean sea level. The lacustrine deposits generally consist of clayey, alkaline surface soils over stratified subsoils. Some of the "slick spot" soils in the ancestral lakebed contain high amounts of exchangeable sodium and are characterized by a lack of vegetation and cracked surfaces.

Bars, spits, and hooks from the ancestral Lake Terreton are well preserved on the modern landscape near Test Area North (TAN). The deposits near TAN are generally quite saline and support a variety of salt-tolerant plant species.

Patches of sand throughout the ancestral lake area overlay the clayey lake deposits and are believed to have originated from the beaches of the Lake Terreton or the Big Lost or Snake rivers. The sands on the northeast end of the INEEL Site are deposited in elongated dunes, which are likely still shifting like the St. Anthony Sand Dunes, which may have similar origins. The sandy deposits typically support big sagebrush and Indian ricegrass, thus offering comparably tall, unique habitats.

Another set of significant playas on the INEEL is the spreading areas located on the southern end of the site. The spreading areas also contain silty and clayey sediments of various depths.

Playas in general are attractive for development because of the deep silty deposits; however, the soils may be subject to flooding and cracking. The shrink-swell capacity of the soils in areas under consideration for development should be checked, and the flooding potential of the surrounding basin should be evaluated. Soil cracking can lead to ruptured roadways and foundations. Soil salinity may preclude agricultural development in the playas and may limit the potential of the land for grazing. Soils from the playas may be easily excavated for fill materials, but again care must be taken to determine the shrink-swell capacity.

4.4.4 Colluvial Deposits

Colluvial deposits are prevalent along the base of the mountainous slopes on the west side of the INEEL and surrounding the East and Middle buttes. Generally, the soils in these deposits consist of gravels. Very little information is available about the soils within these deposits.

Soils developed within the colluvial deposits are subject to erosion, have comparably short growing seasons, and are generally suitable for rangeland and wildlife.

4.5 Meteorology

The National Oceanic and Atmospheric Administration (NOAA) and its predecessor have operated meteorological observation programs at the INEEL since 1949. The NOAA staff makes a full range of hourly and daily meteorological observations. The meteorological monitoring can be used to help model the potential atmospheric transport of contaminants. The atmospheric transport of contaminants is controlled by the following physical parameters: particle size, climate, local meteorology, local topography and large structures or buildings on-Site, and contaminant source strength. A more complete description of the atmospheric monitoring, of the aspects of natural phenomena and physical parameters that are necessary to evaluate impacts from atmospheric transport of potential contaminants is discussed in the Comprehensive RI/FS for WAGs 6 and 10, OU 10-04 (DOE/ID 2001).

4.5.1 Climate

Presently, thirty three meteorological observation stations are in operation at or surrounding the INEEL. Three stations are equipped to measure wind speed and air temperature at multiple levels up to 76 m (250 ft) above the ground. These three towers are located at Central Facilities Area (CFA), Argonne National Laboratory-W (ANL-W), and the Test Reactor Area (TRA). Atmospheric humidity is recorded at CFA and ANL-W. The precipitation and air temperature at the 1.5-m (5-ft) level are recorded at CFA.

A station at TRA has been operational since 1971 and is used to measure windspeed and direction 15 m (50 ft) above the ground. A primary observation station, Grid 3 (GRD3), is located approximately 5 km (3 mi) east-northeast of the TRA station. The GRD3 station was put into service in 1957 and is used to measure windspeed and direction at multiple levels. Since 1979, air temperature at multiple levels also has been recorded at the station. The longest and most complete record of meteorological observations exists for the CFA station. Most of the information presented in this section is summarized from a 1989 climatography report map of the INEEL (Clawson et al. 1989), which compiled weather recordings for the period from 1949 to 1988. Air mass characteristics, proximity to moisture sources, the angle of solar incidence, temperature, and other effects caused by latitude differences would be expected to be similar for all locations at the INEEL; therefore, extrapolation of meteorological data from CFA to other locations at the INEEL is possible (Bowman et al. 1984).

The climate at the INEEL is influenced by the regional topography and upper-level wind patterns over North America. The Rocky Mountains and the Snake River Plain (SRP) help to create a semiarid climate with an average summer-daytime maximum temperature of 28°C (83°F) and an average winter-daytime maximum temperature of -0.5°C (31°F). Infrequent cloud cover over the region allows intense solar heating of the ground surface during the day, and the low absolute humidity allows significant radiant cooling at night. These factors create large temperature fluctuations near the ground (Bowman et al. 1984). During a 22-year period of meteorological records (1954 through 1976), temperature extremes at the INEEL have varied from a low of -41°C (-43°F) in January to a high of 39°C (103°F) in July (Clawson et al. 1989).

4.5.2 Local Meteorology

The average relative humidity at the INEEL ranges from a monthly average minimum of 15% during August to a monthly average maximum of 81% during February and December. The relative humidity is related to diurnal temperature fluctuations. Relative humidity generally reaches a maximum just before sunrise (the time of lowest temperature) and a minimum in the late afternoon (time of maximum daily temperature) (Vandeusen and Trout 1990).

The average annual precipitation at the INEEL is 21.5 cm (8.5 in). The months with the highest precipitation rates are May and June, and the month with the lowest is July. Snowfall at the INEEL ranges from a low of about 30.5 cm (12 in.) per year to a high of about 102 cm (40 in.) per year, with an annual average of 66 cm (26 in.). Normal snowfall occurs from November through April, though occasional snowstorms occur in May, June, and October (Vandeusen and Trout 1990). While climate change over the next 100 years can not at this time be predicted with certainty, hydrologic and water resource modeling indicates flooding may be a more important consequence of climate change in Idaho than drought (*Assessment of Climate-Change Impacts on Water Resources of the Western United States,* Kenneth M. Strzepek, Dept. of Civil, Environmental and Architectural Engineering, University of Colorado, Boulder, Colorado, in Proceedings of the Rocky Mountain/Great Basin Regional Climate-Change Workshop, Feb. 16-18, 1998, Salt Lake City, Utah).

A statistical analysis of precipitation data from CFA for the period from 1950 through 1990 was made to determine estimates for the 25- and 100-year maximum 24-hour precipitation amounts and 25- and 100-year maximum snow depths (Sagendorf 1991). Results from this study indicate 3.43 cm (1.35 in.) of precipitation for a 25-year, 24-hour storm event, and 4.1 cm (1.6 in.) of precipitation for a 100-year, 24-hour storm event. The 25-year maximum snow depth is 57.4 cm (22.6 in.), and the 100-year maximum snow depth is 77.8 cm (30.6 in.) (Sagendorf 1991).

Potential annual evaporation from saturated ground surface at the INEEL is approximately 91 cm (36 in.). Eighty percent of this evaporation occurs between May and October. During the warmest month (July), the potential daily evaporation rate is approximately 0.63 cm/day (0.25 in./day). During the coldest months (December through February), evaporation is low and may be insignificant. Transpiration by native vegetation on the INEEL approaches the total annual precipitation input. Potential evapotranspiration is at least three times greater than actual evapotranspiration (Kaminsky et al. 1993).

The local topography, mountain ranges, and large-scale weather systems influence the local meteorology. The orientation of the bordering mountain ranges and the general orientation of the eastern SRP play an important role in determining the wind regime. The INEEL is in the belt of prevailing westerly winds, which are normally channeled across the eastern SRP. This channeling usually produces a west-southwesterly or southwesterly wind. When the prevailing westerlies at the gradient level (approximately 1,500 m [5,000 ft] above ground) are strong, the winds channeled across the eastern SRP between the mountains become very strong. Some of the highest windspeeds at the INEEL have been observed under these meteorological conditions. The greatest frequency of high winds occurs in the spring (Clawson et al. 1989).

April is the month with the highest average monthly windspeed near surface (6 m [20 ft]) height, which for CFA is 15.3 km/h (9.3 mph). December is the month with the lowest average monthly windspeed (Clawson et al. 1989).

The INEEL is subject to severe weather. Thunderstorms with localized tornadoes are observed mostly during the spring and summer, but the tornado risk probability at the INEEL is about 7.8×10^{-5} per year (Bowman et al. 1984). An average of two to three thunderstorms a month occurs from June through August. Thunderstorms accompanied by strong gusty winds may produce local dust storms. Occasionally, a single thunderstorm will exceed the average monthly total precipitation (Bowman et al. 1984). Precipitation from thunderstorms at the INEEL is generally light.

Dust devils, common in the region, can entrain dust and pebbles and transport them over short distances. They usually occur on warm sunny days with little or no wind. The dust cloud may be several tens of meters (yards) in diameter and extend several hundreds of meters (hundred yards) into the air (Bowman et al. 1984).

The vertical temperature and humidity profiles in the atmosphere determine the atmospheric stability. Low levels of turbulence and less vertical mixing characterize stable atmospheres. This results in higher ground-level concentrations of emitted contaminants. The stability parameters at the INEEL range from stable to very unstable. Stable conditions occur mostly at night during strong radiant cooling. Unstable conditions occur during the day during periods of strong solar heating of the surface layer, or whenever a synoptic scale disturbance passes over the region (Bowman et al. 1984).

4.6 Ecology

The INEEL is located in a cool desert ecosystem characterized by shrub-steppe vegetation typical of the northern Great Basin and Columbia Plateau regions. The surface of the INEEL is relatively flat, with several prominent volcanic buttes and numerous basalt flows that provide important habitat for small and large mammals, reptiles, and some raptors. The shrub-steppe communities provide habitat for sagebrush (*Artemisia* spp.) community species. Other communities are dominated by rabbitbrush (*Chrysothamnus* spp.), grasses and forbs, salt desert shrubs (*Atriplex* spp.), and exotic weed species. Juniper woodlands occur near the buttes and in the northwest portion of the Idaho National Engineering and Environmental Laboratory (INEEL). These woodlands provide important habitat for raptors and large mammals. Limited riparian communities exist along intermittently flowing waters of the Big Lost River and Birch Creek drainages. Figure 1-2 depicts specific physical features of the INEEL, such as the Big Lost River and nearby mountain ranges and buttes.

Vegetation communities of the INEEL have been characterized and mapped using LANDSAT imagery data (Kramber et al. 1992). Sagebrush communities occupy most of the INEEL, but communities dominated by salt bush, juniper, crested wheatgrass, and Indian ricegrass are also present and distributed throughout the INEEL. Exotic plant species including cheatgrass (*Bromus tectorum*), halogeton (*Halogeton glomeratus*), and Russian thistle (*Salsola kali*) are established, particularly in disturbed areas. Crested wheatgrass (*Agropyron cristatum*), a European bunchgrass seeded in the late 1950s, dominates disturbed areas where it was used to provide cover and to hold soils.

The sagebrush communities consist of a shrub overstory with an understory of perennial grasses and forbs. The most common shrub is Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*). Basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*) may dominate or be codominant with Wyoming big sagebrush on sites having deep soils or sand accumulations (Shumar and Anderson 1986). Big sagebrush communities occupy most of the central portions of the INEEL. Green rabbitbrush (*Chrysothamnus viscidiflorus*) is the next most abundant shrub. Other common shrubs include winterfat (*Krascheninnikovia lanata*), spiny hopsage (*Grayia spinosa*), and gray rabbitbrush (*Chrysothamnus nauseosus*). Communities dominated by Utah juniper (*Juniperus osteosperma*) and three-tipped sagebrush (*Artemisia tripartita*) or black sagebrush (*Artemisia nova*), or both, are found along the periphery of the INEEL on slopes of the buttes on-Site and foothills of adjacent mountain ranges to the northwest.

The understory of grasses and forbs includes the rhizomatous thick-spiked wheatgrass (*Elymus lanceolatus*) as the most abundant grass. Bottlebrush squirreltail (*Elymus elymoides*), Indian ricegrass (*Oryzopsis hymenoides*), and needle-and-thread (*Stipa comata*) are common bunchgrasses. Patches of creeping wildrye (*Leymus triticoides*) and western wheatgrass (*Pascopyrum smithii*) are locally abundant. Communities dominated by Basin wildrye (*Leymus cinereus*) are found in scattered depressions between lava ridges and in other areas having deep soils. Bluebunch wheatgrass (*Pseudoroegneria spicata*) is common at slightly higher elevations in the southwest and east of the INEEL. Prickly phlox (*Leptodactylon pungens*) is a common forb.

Limited riparian communities including cottonwood, willow, waterbirch, and chokecherry occur along the Big Lost River and Birch Creek. Intermittent natural wetlands include the rivers and creeks, playas that may fill in the spring, and the Big Lost River sinks. Anthropogenic wetlands include permanent evaporation ponds and drainage ditches as well as a series of spreading areas near the southwest corner of the site. The spreading areas are used to contain water from the Big Lost River when high flow occurs.

According to the 1997 *INEEL Comprehensive Facility and Land Use Plan* (DOE-ID 1997), 275 vertebrate species have been observed at the INEEL, including 43 mammal, 210 bird, 11 reptile, nine fish, and two amphibian species. Seasonal or migratory visitors compose the majority of the species. A large number of the seasonal vertebrates are birds. Among these species is the bald eagle, which is seen on or near the Site during winter. Raptors and songbirds are important ecological components of the sagebrush-steppe community. The INEEL is inhabited by 14 species of sparrows and allies, six species of swallows, 20 species of ducks and geese, and 24 species of raptors (Craig 1979; Arthur et al. 1984).

Thirty-four species observed at the INEEL are considered game species; of these, waterfowl constitute the largest number of species present. Waterfowl use wetland and riparian habitat associated with the Big Lost River and ponds or impoundments at INEEL facilities. However, the most common game species are the mourning dove (*Zenaida macroura*), pronghorn, and sage grouse found in upland habitats. The INEEL provides an important habitat for big game. Approximately 30% of Idaho's pronghorn population may use the INEEL for winter range (DOE-ID 1997). In addition, a small population of elk (*Cervus elaphus*) has become resident on the INEEL. Because of hunting restrictions, this herd of elk grew dramatically from a very small number. To abate damage to crops on adjacent lands in 1993, the INEEL and the State of Idaho implemented a live-trap removal program to limit the size of the elk population (INEL 1993). Some small mammal species such as the black-tailed jackrabbit (*Lepus californicus*) exhibit large population fluctuations and influence the abundance, reproduction, and migration of predators such as the coyote (*Canis latrans*), bobcat (*Felis rufus*), and raptors. Other observed predators include mountain lions and badgers.

The biological diversity of invertebrate fauna at the INEEL has not been investigated extensively; however, 740 insect species have been collected and identified at the INEEL. The harvester ant (*Pogonomyrmex salinus*), in particular, has received attention during the past decade because of its general importance in desert ecosystem energy cycling (Clark and Blom 1988; 1991). At the nearby Craters of the Moon National Monument, where a thorough invertebrates inventory has been done, 2,064 species were found (DOE 1997); therefore, many more insect species may be present at the INEEL.

Six fish species have been observed in the Big Lost River on the INEEL during years when water flow is sufficient (Arthur et al. 1984). The river flows intermittently across about 50 km (31 mi) of the INEEL, from southwest to north, before it terminates in the Big Lost River sinks. Because of periods of drought and upstream water diversion for agricultural and flood-prevention purposes, flow does not reach the INEEL section of the river for years at a time; therefore, aquatic species are not present in the INEEL section of the river during such periods.

The only permanent sources of surface water on the INEEL are manmade ponds where flows are sustained through facility operations. These ponds represent important habitat on the INEEL that would not exist otherwise. The role and ecological significance of ephemeral playa wetlands on the INEEL has not been studied and is poorly understood (Hampton et al. 1995). But, because these areas hold water for various periods, they may be important as breeding habitat for insects and may supply physiological water needs for bird, mammal, and reptile species. These areas also produce increased vegetation suitable for cover and forage.

Sagebrush communities at the INEEL typically support a number of species including sage grouse (*Centrocercus urophasians*), sage sparrow, (*Amphispiza belli*), pygmy rabbit (*Brachylagus idahoensis*), and pronghorn (*Antilocapra americana*). Rock outcropping associated with these communities also provides habitat for species such as bats and woodrats (*Neotoma cinerea*). Grasslands serve as habitat for species including the western meadowlark (*Sturnella neglecta*) and mule dear (*Odocoileus hemionus*). Facility structures at the INEEL also provide important wildlife habitat. Buildings, lawns, ornamental vegetation, and ponds are used by a number of species such as waterfowl, raptors, rabbits, and bats. Aquatic vertebrates are supported year-round by habitat provided by facility treatment ponds, waste ponds, and facility drainages (Cieminski 1993).

Threatened or endangered species (T/E), species of concern, and sensitive species that use habitats at the INEEL are listed on Table 4-3. T/E species include the peregrine falcon (*Falco peregrinus*) and bald eagle (*Haliaeetus leucocephalus*). In addition to the bald eagle and peregrine falcon, twenty-four species important to agencies including the U.S. Fish and Wildlife Service, Idaho Department of Fish and Game, U.S. Forest Service, and BLM have been observed at the INEEL (see Table 4-3). Former Category 2 (C2) species of interest include the northern goshawk (*Accipiter gentilis*), ferruginous hawk (*Buteo regalis*), loggerhead shrike (*Lanius ludovicianus*), burrowing owl (*Athene cunicularia*), black tern (*Chlidonias niger*), white-faced ibis (*Plegadis chihi*), trumpeter swan (*Cygnus buccinator*), pygmy rabbit (*Brachylagus idahoensis*), Townsend's western big-eared bat (*Corynorhinus townsendii*), long-eared myotis (*Myotis evotis*), small-footed myotis (*Myotis ciliolabrum*), and the sagebrush lizard (*Sceloporus graciosus*). The USFWS no longer maintains a candidate species (C2) listing but addresses former C2 species as "species of concern" (USFWS 1996). The C2 designation is retained here to maintain the consistency with INEEL ERAs conducted prior to the change in USFWS listing procedures.

Ecological research has been conducted at the INEEL since the 1950s. Organizations participating in this research include DOE-ID, the Environmental Science and Research Foundation, the Environmental and Life Science Department of Lockheed Martin Idaho Technologies Company (LMITCO), and various universities such as Idaho State University, University of Idaho, Colorado State University, and Washington State University. The *Guidance Manual for Conducting Screening-Level Ecological Risk Assessments at the INEL* (VanHorn, Hampton, and Morris 1995) provides a summary of the previous ecological investigations pertinent to the INEEL.

Table 4-3. Threatened and endangered species, species of concern, and sensitive species that may be found on the INEEL.a Species in bold are individually addressed in the ecological risk assessment process.

Common Names	Scientific Name	Federal Status[b,c]	State Status[c]	BLM Status[c]	USFS status[c]
Plants					
Lemhi milkvetch	*Astragalus aquilonius*	—	S	S	S
Painted milkvetch[e]	*Astragalus ceramicus var. apus*	3[c]	R	—	—
Plains milkvetch	*Astragalus gilviflorus*	NL	1	S	S
Winged-seed evening primrose	*Camissonia pterosperma*	NL	S	S	—
Nipple cactus[e]	*Coryphantha missouriensis*	NL	R	—	—
Spreading gilia	*Ipomopsis (=Gilia) polycladon*	NL	2	S	—
King's bladderpod	*Lesquerella kingii var. cobrensis*	—	M	—	—
Tree-like oxytheca[e]	*Oxytheca dendroidea*	NL	R	R	—
Inconspicuous phacelia[d]	*Phacelia inconspicua*	C2	SSC	S	S
Ute ladies' tresses[f]	*Spiranthes diluvialis*	LT	—	—	—
Puzzling halimolobos	*Halimolobos perplexa var. perplexa*	—	M	—	S
Birds					
Peregrine falcon	**Falco peregrinus**	**LE**	**E**	**—**	**—**
Merlin	*Falco columbarius*	NL	—	S	—
Gyrfalcon	*Falco rusticolus*	NL	SSC	S	—
Bald eagle	***Haliaeetus leucocephalus***	**LT**	**T**	**—**	**—**
Ferruginous hawk	***Buteo regalis***	**C2**	**SSC**	**S**	**—**
Black Tern	***Chlidonias niger***	**C2**	**—**	**—**	**—**
Northern pygmy owl[d]	*Glaucidium gnoma*	—	SSC	—	—

Table 4-3. (continued)

Common Names	Scientific Name	Federal Status[b,c]	State Status[c]	BLM Status[c]	USFS status[c]
Burrowing owl	***Athene (=Speotyto) cunicularia***	**C2**	**—**	**S**	**—**
Common loon	*Gavia immer*	—	SSC	—	—
American white pelican	*Pelicanus erythrorhynchos*	—	SSC	—	—
Great egret	*Casmerodius albus*	—	SSC	—	—
White-faced Ibis	***Plegadis chihi***	**C2**	**—**	**—**	**—**
Long-billed curlew	*Numenius americanus*	3c	—	S	—
Loggerhead shrike	***Lanius ludovicianus***	**C2**	**NL**	**S**	**—**
Northern goshawk	***Accipiter gentilis***	**C2**	**S**	**—**	**S**
Swainson's hawk	*Buteo swainsoni*	—	—	S	—
Trumpeter Swan	***Cygnus buccinator***	**C2**	**SSC**	**S**	**S**
Sharptailed grouse	*Tympanuchus phasianellus*	C2	—	S	S
Boreal owl	*Aegolius funereus*	—	SSC	S	S
Flammulated owl	*Otus flammeolus*	—	SSC	—	S
Mammals					
Gray wolf	***Canis lupus***	**LE/XN**	**E**	**—**	**—**
Pygmy rabbit	***Brachylagus (=Sylvilagus) idahoensis***	**C2**	**SSC**	**S**	**—**
Townsend's western big-eared bat	***Corynorhinus (=Plecotus) townsendii***	**C2**	**SSC**	**S**	**S**
Merriam's shrew	*Sorex merriami*	—	S	—	—
Long-eared myotis	***Myotis evotis***	**C2**	**—**	**—**	**—**
Small-footed myotis	***Myotis ciliolabrum (=subulatus)***	**C2**	**—**	**—**	**—**
Western pipistrelle[d]	*Pipistrellus hesperus*	NL	SSC	—	—
Fringed myotis[d]	*Myotis thysanodes*	—	SSC	—	—
California Myotis[d]	*Myotis californicus*	—	SSC	—	—
Reptiles and Amphibians					
Northern sagebrush lizard	***Sceloporus graciosus***	**C2**	**—**	**—**	**—**
Ringneck snake[d]	*Diadophis punctatus*	C2	SSC	S	—
Night snake[e]	*Hypsiglena torquata*	—	—	R	—
Insects					
Idaho pointheaded grasshopper[d]	*Acrolophitus punchellus*	C2	SSC	—	—
Fish					
Shorthead sculpin[d]	*Cottus confusus*	—	SSC	—	—

a. This list was compiled from the U.S. Fish and Wildlife Service (USFWS) (letter dated July 16, 1997) the Idaho Department of Fish and Game Conservation Data Center threatened, endangered, and sensitive species for the State of Idaho (CDC 1994 and IDFG web site 1997) and RESL documentation for the INEL (Reynolds 1994; Reynolds et al. 1986).

b. The USFWS no longer maintains a candidate (C2) species listing but addresses former listed species as "species of concern" (USFWS April 30, 1996). The C2 designation is retained here to maintain consistency between completed and ongoing INEEL ERAs.

c. Status Codes: INPS=Idaho Native Plant Society; S=sensitive; 2=State Priority 2 (INPS); 3c=no longer considered for listing; M=State monitor species (INPS); NL=not listed; 1=State Priority 1 (INPS); LE=listed endangered; E=endangered; LT=listed threatened; T=threatened; XN = experimental population, non-essential; SSC=species of special concern; and C2 = see item b, formerly Category 2 (defined in CDC 1994). BLM=Bureau of Land Management; R = removed from sensitive list (non-agency code added here for clarification).

d. No documented sightings at the INEEL, however, the ranges of these species overlap the INEEL and are included as possibilities to be considered for field surveys.

e. Recent updates resulting from Idaho State Sensitive Species meetings (BLM, USFWS, INPS, USFS) - (INPS 1995; 1996; 1997; 1998)

f. United States Forest Service (USFS) Region 4

The INEEL is considered an ecological treasure (Anderson 1999). A special benefit of the site being set aside for government use was the protection of what is arguably the largest expanse of protected sagebrush-steppe habitat anywhere in the United States. Approximately 40% of the INEEL has not been grazed for the past 45 years. Recognizing the importance of this undisturbed area as an ecological field laboratory, the area was also designated as a National Environmental Research Park (NERP) in 1975. This is one of only two such parks in the United States that allows comparative ecological studies in sagebrush-steppe ecosystems (DOE-ID 1997).

July 17, 1999, the Sagebrush Steppe Ecosystem Reserve was created at the INEEL. This reserve will conserve 74,000 acres of unique habitat on the northwest portion of the INEEL. The INEEL contains some of the last sagebrush steppe ecosystem in the United States. This action recognized that the INEEL has been a largely protected and secure facility for 50 years and that portions are valuable for maintaining this endangered ecosystem.

Several wildlife species are found only or primarily in sagebrush habitats throughout their range. About 100 bird, 70 mammal, and 23 amphibian and reptile species in the Great Basin rely to some degree on sagebrush habitat for shelter and food. Some are sagebrush obligates—sagebrush lizard, pygmy rabbit, pronghorn, sage sparrow, brewer's sparrow, sage grouse, loggerhead shrike, and sagebrush vole, which cannot survive without plenty of high-quality sagebrush and its associated perennial grasses and forbs. Other species depend on sagebrush for a significant portion of their diet. For example, pronghorn depend on sagebrush for nearly 90 percent of their diet (Lipske 2000).

As part of the overarching concerns at the INEEL for sustaining a healthy environment, the OU 10-04 comprehensive investigation (DOE-ID 2001) included the OU 10-04 INEEL-wide ecological risk assessment. Concern about the impact of the INEEL's activities on the environment has been reflected in long-term monitoring, research, and analysis of the environment during the 50 years that the INEEL has been in operation. The INEEL-wide ERA used a multiple line of evidence approach to evaluate the risk. This approach included assessments of ecologically sensitive areas, ecological sampling on site, breeding bird survey, long-term vegetation transect, radiological biota studies, air dispersion modeling, biological surveys for sensitive species and/or habitat, spatial distribution of contamination, and WAG ERA summaries. The spatial analysis concluded that less than 20 percent of the habitats present on the INEEL are lost to facility activities and that there is minimal risk to the INEEL's diverse plant and animal communities. However, based on the multiple uncertainties and assumptions in the assessment it was determined that ecological monitoring would be critical to ensure protection of this important ecosystem (DOE-ID 2001).

4.7 Demography and Land Use

4.7.1 Demography

Populations potentially affected by Waste Area Groups (WAGs) 6 and 10 activities include government contractor personnel employed at the INEEL, ranchers who graze livestock in areas on or near the INEEL, occasional hunters on or near the INEEL, and residential populations in neighboring communities. No resident populations are located within the INEEL Site boundary, and no residents are located in the vicinity of WAGs 6 or 10 (Figure 4-20).

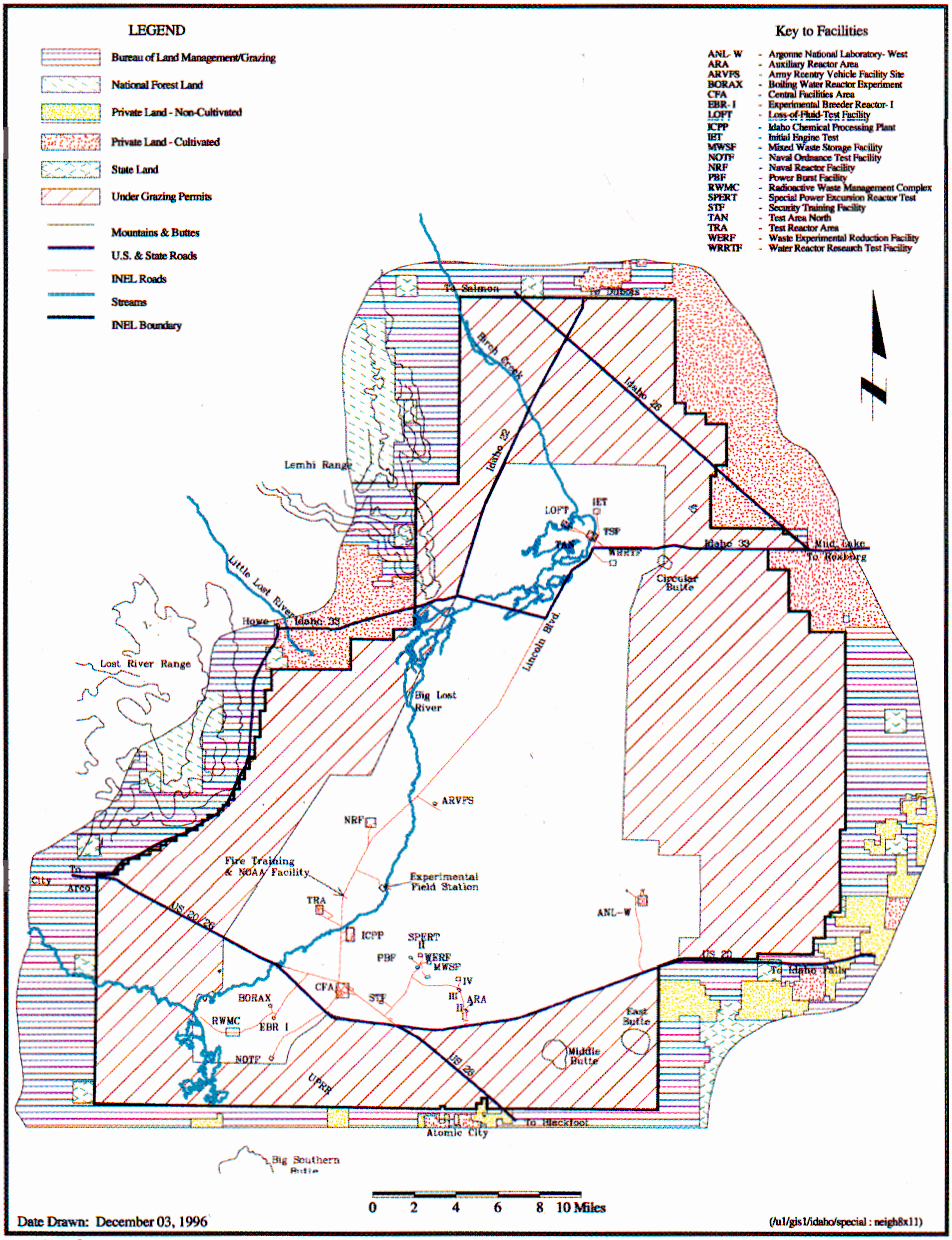


Figure 4-20. Land ownership distribution in the vicinity of the INEEL and on-Site areas open for permit grazing.

In August 1996, the INEEL employed 8,044 contractor and government personnel; though none are employed at the WAGs 6 or 10 sites with the exception of tour guides at the Experimental Breeder Reactor-I (EBR-I) facility from Memorial Day to Labor Day. Five counties border the INEEL: Bingham, Bonneville, Butte, Clark, and Jefferson. Major communities include Blackfoot and Shelley in Bingham County, Ammon and Idaho Falls in Bonneville County, Arco in Butte County, and Rigby in Jefferson County. Population estimates for the counties surrounding the INEEL and the largest population centers in these counties are shown in Table 4-4.

Table 4-4. The 1996 population estimates for counties surrounding the INEEL and selected communities.[a]

Location	Population Estimate
Bingham County	41,188
Blackfoot	10,406
Shelley	3,803
Clark County	822
Bonneville County	79,531
Ammon	5,849
Idaho Falls	48,079
Butte County	3,008
Jefferson County	18,786
Rigby	2,703

a. Source: Idaho Department of Commerce, July 1998.

4.7.2 Land Use

The Bureau of Land Management (BLM) classifies INEEL land as industrial and mixed use (DOE 1991). The primary INEEL land uses are facility and program operations and buffers and safety zones around the facilities. Virtually all the work at the INEEL is performed within the Central Facility Area (CFA) and the Test Reactor Area (TRA). Approximately 2% (4,600 ha [11,400 acres]) of the Site is used for building and support structures totaling 279,000 m^2 (3,000,000 ft^2) of floor space and supporting infrastructure operations. The remaining INEEL land, which is largely undeveloped, is used for environmental research, ecological preservation, sociocultural preservation, grazing, and some forms of recreation (DOE-ID 1997).

A National Environmental Research Park (NERP), designated in 1975, is used as a controlled outside laboratory in which scientists can study environmental changes caused by human activities. A number of INEEL facilities are capable of producing stresses on the environment. Opportunities for significant research exist in Site-wide studies of these stresses and potential mitigative measures. A substantial body of geological, hydrological, wildlife, vegetation, and meteorological information has been collected for more than 40 years. The developed area within the INEEL is surrounded by a 1,295-km^2 (500-mi^2) buffer zone of grazing land for cattle and sheep (DOE 1991). The U.S. Department of the Interior administers the area through BLM grazing permits. Grazing is not allowed within 3.2 km (2 mi.) of any nuclear facility, and dairy cattle are not permitted. The area used for grazing ranges from 121,410 to 141,645 ha (300,000 to 350,000 acres). The U.S. Sheep Experiment Station, located approximately 42.6 km (26.5 mi) northeast of the Site, uses a 364-ha (900-acre) portion of the INEEL as a winter feed lot for approximately 5,000 sheep.

Depredation hunts, managed by the Idaho Department of Fish and Game, are permitted on-Site during selected years. Hunters are allowed 0.8 km (0.5 mi.) inside the INEEL boundary on portions of the northeastern and western borders of the Site (Hull 1989).

State Highways 22, 28, and 33 cross the northeastern portion of the Site, and U.S. Highways 20 and 26 cross the southern portion. The public uses a total of 145 km (90 mi.) of paved highways that pass through the INEEL (DOE 1991). Fourteen miles of Union Pacific Railroad traverses the southern portion of the Site. A government-owned railroad runs from the Union Pacific tracks through CFA to NRF, and a spur from the Union Pacific runs to RWMC.

In the counties surrounding the INEEL, approximately 45% of the land is agricultural, 45% is open land, and 10% is urban (DOE 1991). Agricultural uses include production of sheep, cattle, hogs, poultry, and dairy cattle (Bowman et al. 1984). The major crops produced on land surrounding the INEEL are wheat, alfalfa, barley, potatoes, oats, and corn (see Table 4-5). Sugar beets are grown within about 64 km (40 mi) of the INEEL in the vicinity of Rockford, Idaho, in central Bingham County and southeast of the INEEL. Most of the land surrounding the INEEL is owned by private individuals or the U.S. Government and is administered by the BLM.

Table 4-5. Acreage of major crops harvested in counties surrounding the INEEL (1994–95).[a]

County	Wheat	Alfalfa	Barley	Potatoes	Sugar beets	Oats	Silage Corn
Bingham	129,700	52,300	26,700	65,800	11,500	600	
Bonneville	59,500	43,100	61,100	37,900		500	
Butte	8,700	32,400	15,600	3,400		500	
Clark	11,700	16,500	1,000	12,500		200	
Jefferson	44,600	92,100	49,000	26,600		800	1,400

a. Source: Idaho 1996.

The INEEL is likely to continue as an industrial and research facility (DOE-ID 1997), with moderate growth expected for the next 20 years. Agricultural and open land will continue to surround the INEEL. The WAG 6 EBR-I site will remain recreational and industrial, and the BORAX site will remain industrial for a minimum of 100 years. Waste Area Group 10 will remain agricultural, industrial, and recreational for the next 100 years. Other less likely INEEL land uses include agriculture and the return of on-Site areas to their natural, undeveloped state. Future land use is addressed in the INEEL future land-use scenarios document (DOE-ID 1997).

4.7.3 Water Use and Supply

Production wells to the SRP aquifer are the source of all water used at the INEEL. Approximately 8 million m^3/year (282 million ft^3/year) are drawn from the 30 on-Site production wells (DOE 1991). Active production wells are located at CFA, RWMC, ANL-W, TAN, NRF, TRA, and INTEC.

Upstream of the INEEL, the Big Lost River, Little Lost River, and Birch Creek are used as sources of water for agriculture. In years of high flow, Birch Creek terminates at a playa near the north end of the Site. The Little Lost River terminates at a playa just north of the central north-western boundary of the INEEL. The Big Lost River flows onto the INEEL near the Sites south-western corner, bends to the northeast, and flows north-eastward to the Big Lost River playas. The surface water that reaches the INEEL is not used for any purpose. No surface-water streams flow off the INEEL with the potential exception of diverted water exiting Spreading Area D during extremely wet or high water conditions.

Regionally, approximately 1.8 billion m^3/yr (63 billion ft^3/yr) of water is drawn from the aquifer in the eastern SRP for agricultural use (DOE 1991). Most cattle and sheep grazing in the vicinity of the INEEL is near wells or spring developments. Drinking water in the region is obtained almost exclusively from the aquifer.

4.8 Listing of Waste Area Groups at the Idaho National Engineering and Environmental Laboratory

To manage the investigations needed to determine appropriate remedial actions, the INEEL was divided into 10 WAGs (Figure 1-2) in a tri-party agreement with the EPA Region 10, DOE-ID, and Idaho Department of Health and Welfare (IDHW) (DOE-ID 1991). Within each WAG, known or suspected areas of contamination are assigned to an OU as a means of controlling investigation and cleanup activity. This strategy allows the EPA Region 10, DOE-ID, and IDHW to focus available cleanup resources, schedule remedial actions, and coordinate Comprehensive Environmental Response, Compensation, and Liability Act activities.

The 10 WAGs include the following:

- WAG 1—Test Area North (TAN)
- WAG 2—Test Reactor Area (TRA)
- WAG 3—Idaho Nuclear Technology and Engineering Center (INTEC)
- WAG 4—Central Facilities Area (CFA)
- WAG 5—Power Burst Facility (PBF) and Auxiliary Reactor Area (ARA)
- WAG 6—Experimental Breeder Reactor No. 1 (EBR-1)
- WAG 7—Radioactive Waste Management Complex (RWMC)
- WAG 8—Naval Reactors Facility (NRF)
- WAG 9—Argonne National Laboratory–West (ANL-West)
- WAG 10—Miscellaneous Sites.

The WAG 10 includes miscellaneous surface sites and liquid disposal areas throughout the INEEL that are not included within other WAGs. It also includes regional SRP aquifer concerns related to the INEEL that cannot be addressed on a WAG-specific basis.

4.9 Definitions of Areas Included in this Remedial Investigation/Feasibility Study Work Plan

Individual WAG-specific and WAG 10 scooping meetings for OU 10-04 have resulted in refining the role of WAG 10. The FFA/CO delineates WAG 10 as comprising miscellaneous surface sites and liquid disposal areas throughout the INEEL that are not included within other WAGs and are outside the 9 major facilities. WAG 10 also includes regional Snake River Plain Aquifer concerns related to the INEEL that cannot be addressed on a WAG-specific basis. The boundary of WAG 10 is the INEEL boundary, or beyond as necessary. OU 10-08 also includes sites transferred to OU 10-08 from other OUs, new sites identified post OU-10-04 and a mechanism to evaluate new sites identified post OU 10-08 ROD.

4.9.1 Surface

The Federal Facility Agreement and Consent Order (FFA/CO) defines WAG 10 as the INEEL boundary or beyond, as necessary, to encompass any real or potential impact from INEEL activities and any areas within the INEEL not covered by other WAGs (DOE-ID 1991). The WAG 10 area is defined as the INEEL boundary minus WAGs 1 through 5, 7 through 9, and the Jefferson County landfill (58 FR 249). It was determined that the Jefferson County Landfill site was a no further action site at the time the land was turned over to the Bureau of Land Management to sell to Jefferson County for a multicounty landfill.

The WAG 10 encompasses a large area and much of that area is uncontaminated. The uncontaminated areas were addressed in the OU 10-04 RI/FS and data were presented in the RI/FS to support the no action decisions. Part of the RI/FS process for WAG 10 will be to establish a process for dealing with newly discovered sites that may be within existing WAGs. As these newly discovered sites are turned over to WAG 10 by the discovering WAG, a process developed in the OU 10-08 RI/FS will be implemented to deal with the investigation, characterization and, if necessary, remediation of the newly discovered site.

4.9.2 Groundwater

As defined in the FFA/CO, the WAG 10 groundwater includes “regional Snake River Plain aquifer concerns related to the INEEL that cannot be addressed on a WAG-specific basis. The boundary of WAG 10 is the INEEL boundary, or beyond as necessary to encompass real or potential impact from INEEL activities, and any areas within the INEEL not covered by other WAGs.”

Critical assumptions of the OU 10-08 RI/FS groundwater strategy are that the individual WAGs will model, monitor, and remediate (as needed) to the full extent of their plume, and that the OU 10-08 ROD will select a limited action remedy for groundwater. This limited action remedy will rely principally on monitoring and institutional controls. The strategy assumes that no active groundwater remedial action will be required under OU 10-08 to protect human health and the environment, because individual WAGs will remediate groundwater, as necessary. However, to ensure that important groundwater issues are not missed, WAG 10 will work with and review all major groundwater related issues and decisions rendered by individual WAGs and OU 10-08 will monitor residual groundwater contamination levels throughout the INEEL and downgradient at the INEEL borders. The OU 10-08 ROD and subsequent groundwater monitoring plans will outline plans for future monitoring in the SRP aquifer and integration of 5-year CERCLA reviews Commingled Plumes. A component of the RI groundwater program will be a review of INEEL WAG groundwater plumes and a review of predicted plume geometries after the implementation of the selected remedy. The groundwater plumes will be reviewed for location, size and constituents of concern and any potential for commingling with other known plumes. A summary table will be prepared during the RI indicating the preliminary and final remediation goals for the aquifer at each WAG, and the WAG-specific receptor location where the concentrations must be met during specific time periods. Where individual WAGs have not evaluated commingling of plumes from different sources, the OU 10-08 RI will evaluate commingling by superimposing plumes from different WAGs for specific time periods on the same map. Additional work with each WAG model will be necessary as the plumes generated from each WAGs modeling effort were set into a different SRP aquifer model domain with sometimes not-so-subtle differences in flow characteristics. The modeling has not been consistent and could not be simply overlaid to determine commingling effects. In order to evaluate the extent to which plumes overlap and commingle, the vertical extent of a contaminant plume will be evaluated by drilling a new well and performing vertical profile sampling of that well. In addition, vertical profile sampling conducted by individual WAG's will be used, if available. The available data will be evaluated to determine the need for additional vertical profile sampling.

4.9.2.1 Upgradient, Baseline Groundwater. The aquifer beneath the northern portion of the INEEL contains low levels of nitrates from agricultural practices occurring in the Mud Lake area (Robertson et al., 1974). The background levels of other metals or trace elements entering the site from surface and groundwater flow from the major drainage basins that drain into and below the INEEL will be assessed. The assessment of upgradient water quality for the INEEL will be used to determine the locations of existing wells that could be used for groundwater monitoring in this area. Sampling these wells will provide a record of any contamination moving on to the INEEL from upgradient sources. The WAG 10 responsibilities will be to ensure that periodic sampling is occurring in appropriate upgradient wells to monitor for potential impacts. In addition, any contaminants moving on-site could be used as tracers to estimate travel times in the aquifer and to help locate preferential flow paths.

4.9.2.2 Perched Water-Groundwater Interactions. It is assumed that WAG-specific remedial actions will satisfactorily remediate unacceptable risk posed by any perched water body below specific WAGs.

4.10 References

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